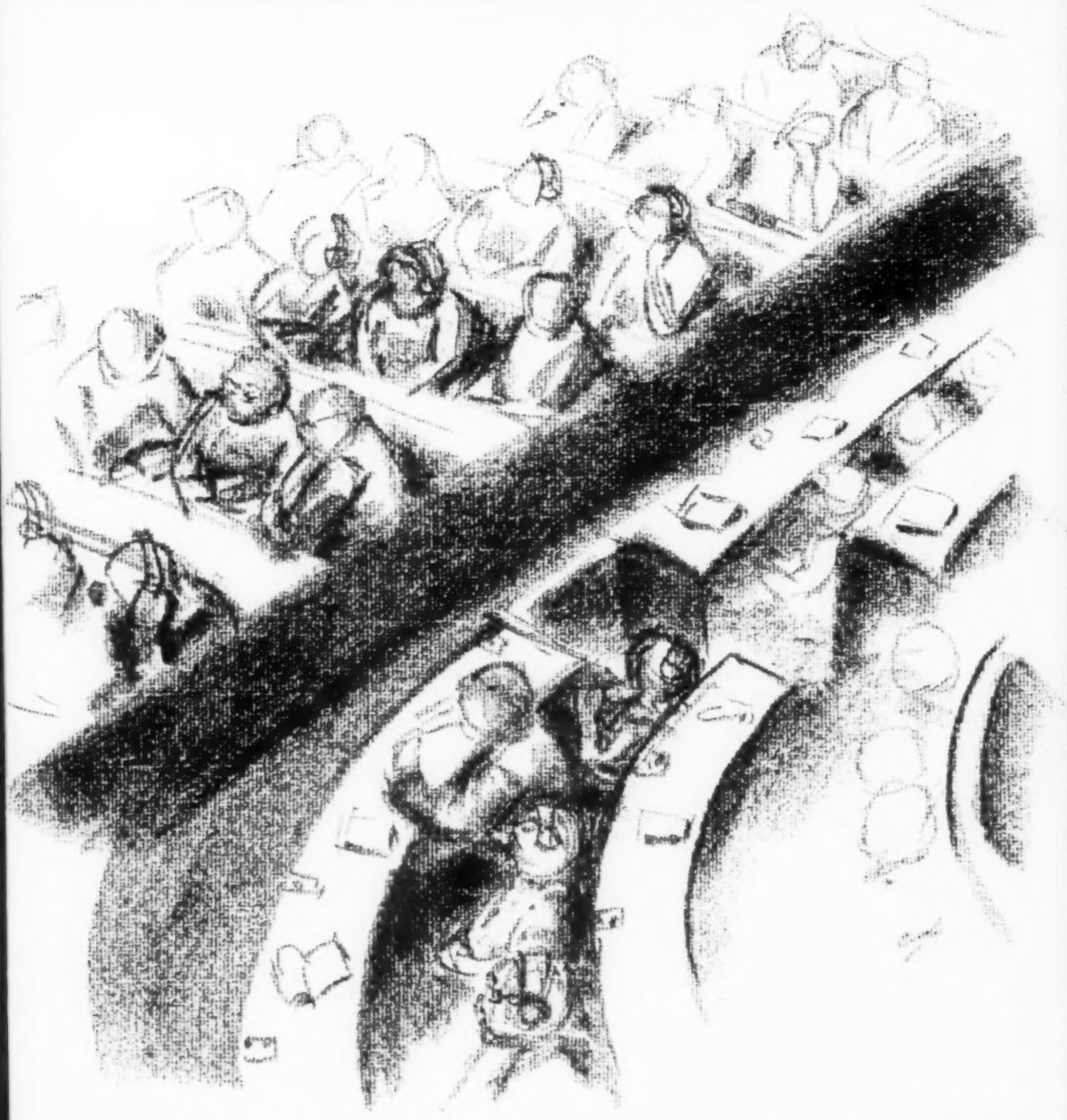
JOURNAL OF

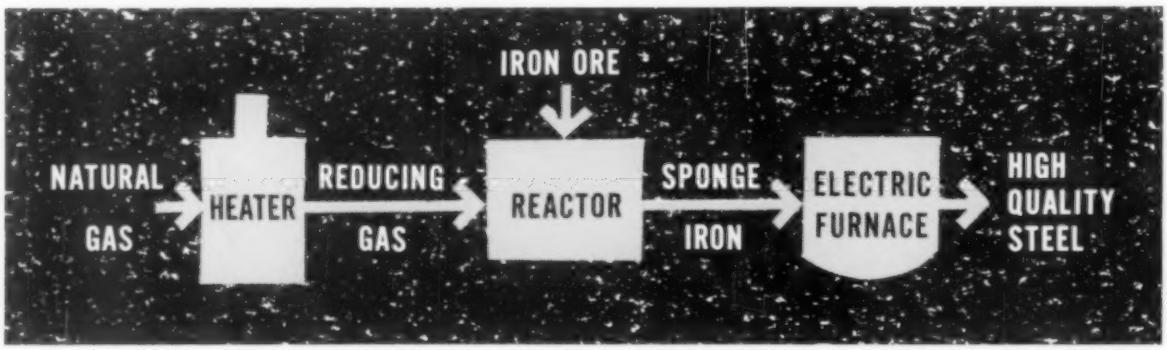
METALS

NOVEMBER 1958



Atoms for Peace Conference . . . Soviet Metallurgy

NEW Sponge Iron Process opens new economics– new areas of operation for steel making



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JOURNAL OF

METALS

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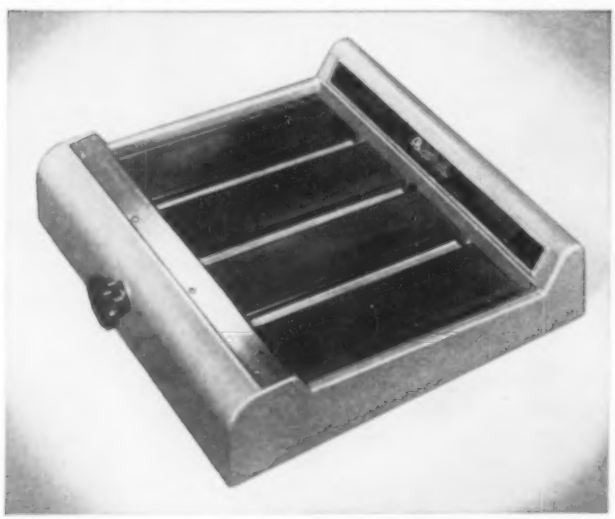
Process Metallurgist, graduate metallurgical engineer, with administrative experience in development and production of flat rolled electrical steels. Apply by letter giving education, experience, and availability. Location, South. W6186.



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BOOKS

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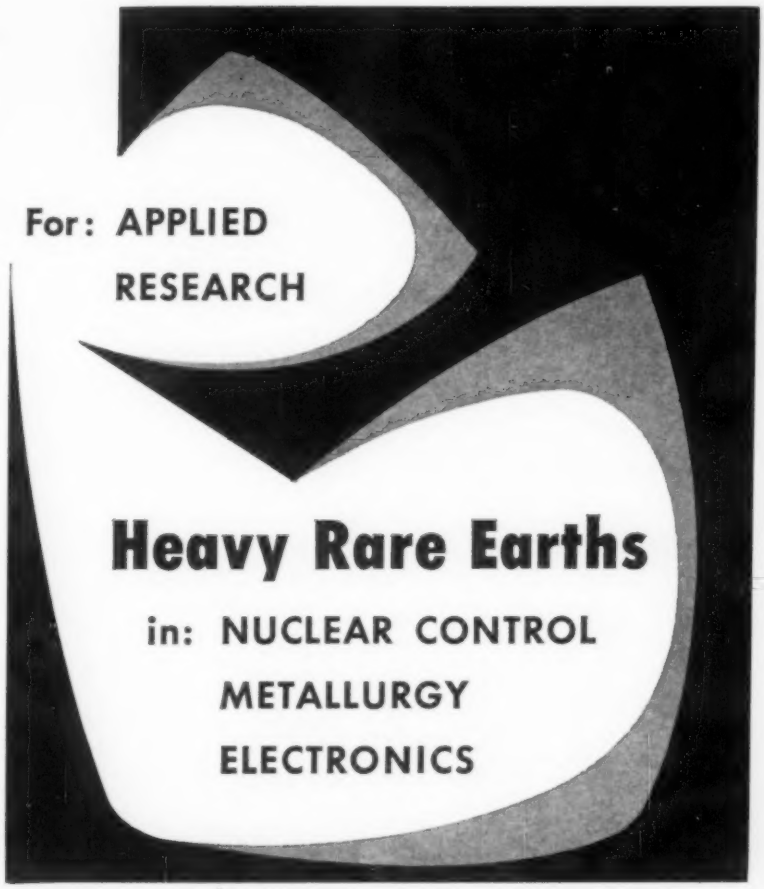
Scientific Societies In The United States, Second Edition, by Ralph S. Bates, *Columbia University Press,* 2960 Broadway, New York 27, N. Y., 297 pp., $6.50, 1958—An historical account of the development of scientific and technological societies in America from their beginnings in the eighteen century to the present. This edition includes a new chapter on the activities of societies since the second World War. The extensive bibliography has been completely revised and contains further sources of information for most of the major and many of the smaller societies.

Symposium On Nondestructive Testing, Special Technical Publication No. 213, *American Society for Testing Materials,* 1916 Race St., Philadelphia 3, Pa., 99 pp., $2.75, 1958—Papers discussing the latest and most widely used techniques of nondestructive testing and their application to materials inspection. Techniques discussed include radiographic testing, magnetic particle and penetrant testing, and ultrasonic testing.

Fundamental Principles Of Transistors, by J. Evans, *D. Van Nostrand Co. Inc.,* 120 Alexander St., Princeton, N. J., 255 pp., $6.75, 1958—A concise explanation of the principles underlying the operation of transistors. A preliminary section describes

(Continued on page 706)



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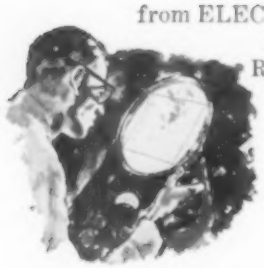

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News of EDUCATION

POWER CONFERENCE

The 21st American Power Conference, sponsored annually by the **Illinois Institute of Technology** in cooperation with a group of educational institutions, and technical societies, including the AIME, will be held on March 31st, and April 1-2 at the Hotel Sherman, Chicago. The conference provides a forum for discussion of problems and exchange of information concerning the electric power industry, and associated activities.

The cooperating colleges and universities are Illinois, Iowa, Iowa State, Michigan, Michigan State, Northwestern, Purdue, Minnesota, Wisconsin, Texas A.&M., New York University, California Institute of Technology, Georgia Institute of Technology, and the Massachusetts Institute of Technology.

Inquiries concerning the conference should be sent to *Conference Director R. A. Budenholzer, Mechanical Engineering Department, Illinois Institute of Technology, 3300 Federal Street, Chicago 16, Illinois.*

FLUOSOLIDS REACTOR PROGRAM

The **University of Arizona, College of Mines** will offer an educational program and symposium on the *Application of the FluoSolids Reactor to the Mineral Industry*, early in 1959. The first part of the educational program will be held for five days, Monday, February 23rd through Friday, February 27th. It is designed for engineers who will have control, or be directly or indirectly connected with the operation of a FluoSolids Reactor. The program will consider fundamentals of chemistry, physics, mathematics, stoichiometry, and metallurgical thermodynamics as they apply to the FluoSolids reactor. The educational program fee is $30.00.

A symposium will form the second part of the program, on Monday and Tuesday, March 2-3. It will be devoted to technical papers, a panel discussion, and a field trip to the new Hayden smelter, owned by Kennecott Copper Corp. A $10.00 symposium fee will include transportation, and one meal during the field trip.

Additional information may be obtained from *Professor Sigmund L. Smith at the College of Mines, University of Arizona, Tuscon, Ariz.* All fees are payable in advance.

The program is planned to follow shortly after the annual meeting of the AIME, in San Francisco from February 15-19.

CONFERENCE ON FRACTURE

A seminar on the *Atomic Mechanisms of Fracture*, sponsored by the **National Academy of Sciences-National Research Council**, will be held in Cambridge, Mass., April 12-14th. Opened to interested persons, the conference will feature invited papers from the U.S. and abroad on the following topics: theoretical aspects of fracture, cleavage, crystalline and non-crystalline fracture, and high-temperature fracture.

The conference is being sponsored jointly by the National Science Foundation, Office of Naval Research, Air Force Office of Scientific Research, and the National Academy of Sciences-National Research Council.

Further information may be obtained from *Dr. B. L. Averbach.*

(Continued on page 708)

2 METALLOGRAPHERS

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BROOKHAVEN NATIONAL LABORATORY

Visited by Physical Metallurgy Group

Fifty-six interested taxpayers assembled at Brookhaven National Laboratory for the first meeting of the 1958-59 season of the Physical Metallurgy Group of the New York Section, AIME. Beginning at 2:30 on the afternoon of October 8, the visitors heard an introductory talk by Dr. R. A. Mayer, Acting Head, Metallurgy division. He described the organization of Brookhaven, which is operated for the Atomic Energy Commission by Associated Universities, Inc., an institution formed by nine sponsoring universities for this purpose. He also mentioned briefly the liquid metal fuel reactor (LMFR) which will be built at Brookhaven within a few years.

Following this introduction, the group was conducted on a tour of various facilities at the Laboratory. The first stop was at the 25 bev. proton synchrotron currently under construction at Brookhaven. This particle accelerator, billed as the *world's largest atom smasher*, is similar in design to the one currently being built at CERN, Switzerland, and described on page 717 of this issue. The group toured the experimental area, the tunnel which will house the accelerator chamber, and the linear accelerator components.

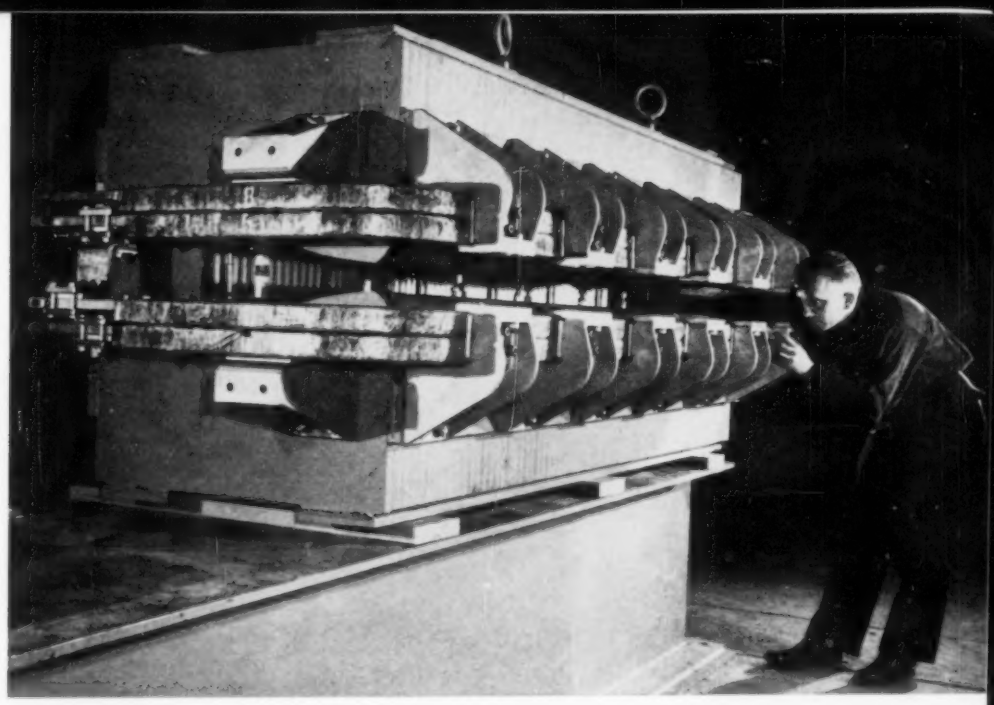
A visit to the large *classical* nuclear reactor, or atomic pile, was also included in the group's itinerary. Following a detailed explanation of the reactor design and principles, an excellent opportunity was afforded to view its operation and to see experiments in progress.

The metallurgy building was, of course, a point of great interest to many of the visitors. Here, in preparation for design and construction of the new reactor (LMFR), a number of thermal loops utilizing both natural and forced convection are in operation for the purpose of evaluating structural materials. Various metallurgical service facilities, including X-ray and metallographic sections, were also to be found in this area.

One facet of the atomic pile's operations was explored in greater detail during the visit to the *hot* chemistry laboratory. Here it was possible to see various studies involving the use of radioisotopes produced by the reactor. These include biological, chemical, and physical investigations of radiation effects.

The last point to be visited was the 4-in. thermal loop, currently under construction. Similar to the ones in the metallurgy building, this loop will, when completed, represent a *pilot* stage in the construction of the LMFR. It will be used to evaluate various structural materials which might be used in the new reactor.

Following the tour, members of the group dined in the cafeteria which is part of the installation at Brookhaven, then reconvened for the technical session, which is a regular part of their meetings. The speaker of the evening, introduced by R. A. Mayer, was John R. Weeks, who discussed *Fuel and Material Technology of a Uranium-Bismuth Reactor*. (The LMFR will probably be a uranium-bismuth reactor). Weeks discussed the results of metallurgical investigations conducted with regard to fuel and structural materials for the LMFR. His talk served admirably to add technical background to the various exhibits which were part of the afternoon tour. In the case of the liquid metal fuel, it was desired to find a metal which combined a low melting point with appreciable solubility of the uranium fuel in the practical range of operating temperatures. Suitability of structural materials was based on mechanical properties at operating temperatures and corrosion behavior with respect to the liquid metal fuel. There was considerable discussion following Mr. Weeks' talk, after which a successful meeting of the Physical Metallurgy Group of the New York Section came to a close.



(Left) Brookhaven's proton synchrotron under construction.

(Right) One of 240 magnets used in the synchrotron.

BROOKHAVEN'S SYNCHROTRON

One of World's Largest

A proton synchrotron similar in design to the one at CERN in Europe, described on p. 717 of this issue, is being built at the Brookhaven National Laboratory in Upton, Long Island, New York. When completed in 1960, the accelerator will produce protons with energy of 25 to 30 bev. The newly available high-energy particles will be used to bombard matter, reacting with atomic nuclei to produce other particles and other forms of energy.

This is not the first synchrotron to be constructed, but it is one of the first to use the principle of strong focusing, which employs specially designed magnets to hold the electrically charged protons on course as they gain energy.

The heart of the synchrotron is 240 "C" shaped magnets arranged in a circle which is ½ mile in circumference. These magnets, generating a force of 10,000 to 13,000 gauss, will be in a subterranean tunnel 12 ft deep. Between the poles of the magnets, which form the jaws of the "C", will be a continuous elliptical vacuum chamber 7 in. in diam and $3\frac{3}{8}$ in. high. The protons will travel through this chamber as they are accelerated to tremendous energy.

The energy of the protons as they are produced in a high-voltage generator is 750,000 ev. They travel through a linear accelerator and gradually reach an energy of 50,000,000 ev, before being ejected into the ½ mile vacuum chamber. As they travel around this accelerator, 12 radio frequency accelerating stations give them boosts in energy so that at the end of their 1 sec travel they have gone around the circular track 350,000 times, and are traveling with an energy of 25 to 30 bev, at a velocity close to the speed of light.

A major problem which scientists encountered in building the synchrotron, was the exacting requirements necessary for each batch of electrical steel from which the magnets were to be made. Each of the 240 magnets had to be as identical as possible, making it necessary to minimize the variation from heat to heat, and from sheet to sheet of the same heat, and even from one section of a sheet to another. To solve this problem, Brookhaven scientists, in conjunction with Baldwin-Lima Hamilton Corp., fabricated magnetic cores by laminating sheets of electrical steel. The cores were strapped and welded under pressure to achieve an extremely high lamination factor (ratio of steel to air along core axis) of 98 pct.

Steel for these large magnets was made by Allegheny Ludlum Steel Corp., and was the largest single order of electrical steel ever produced by the company. More than 3800 tons was used for the Brookhaven job, and delivered over a 9 month period.

With this new synchrotron, scientists at Brookhaven, along with contributing scientists, will find it possible to study the forces which hold the nucleus of the atom together. This will be a great step toward fathoming the complexities of matter in general and the nature of the atom in particular.

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EDITORIAL

GETTING BEHIND THE BUILDING FUND

The Industrial Gifts Campaign for the United Engineering Center is well on its way, with total subscriptions by October 1 in excess of $3½ million, of which corporations in the New York area alone pledged $2.6 million. In the overall campaign, as in other phases of the new engineering center project, members can take pride in the leadership exerted on their behalf by prominent AIME members.

AIME's presidents for the past several years have played active roles in bringing the Center to reality, particular note going to H. DeWitt Smith, one of AIME's representatives on the 15-man steering group; and Andrew Fletcher, President of United Engineering Trustees.

Undertaking a $10-million building program took courage, but it was not undertaken without the most searching analysis of needs, alternatives, and means. It was recognized early in the study that the matter of financing would have lasting effects on the societies and their members. Among the alternatives were these:

1) To disperse the societies and rent office space.
2) To build a new center taking available resources plus a mortgage for the balance.
3) To ask for industrial support of a new center worthy of the profession.

The first alternative meant space costs far higher than in the present building. Reduced services and higher dues must then be faced indefinitely and the unity of the profession would be weakened if not destroyed.

The second possibility would have kept the societies together in their own building, but would again have faced the society membership with higher dues or reduced services or both for years to come.

The third course was deemed the only one of courage *and wisdom*, taking the future into account. Low building space cost and unity of action had proved a bulwark to the Founder Societies through two world wars and a major depression.

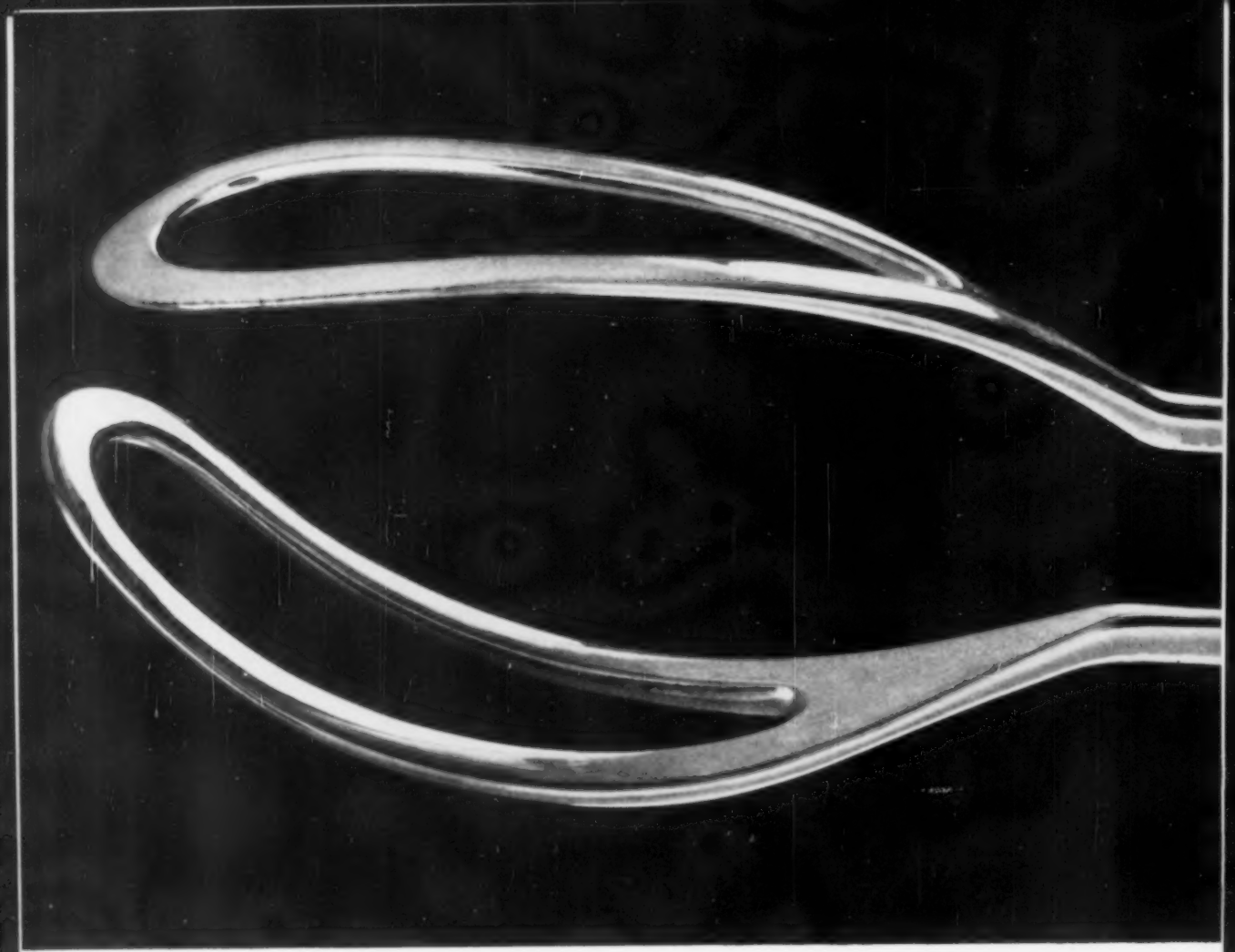
Industry was approached through a group of interested leaders. They gave this reply: "We will help—but what are the engineers willing to do for themselves?" Again, there were alternatives in the means of raising the balance (more than two thirds would be available from reserves and an industrial gifts campaign). Dues could be increased for some years to come; or a membership fund drive for 30 pct of the cost. The second course was chosen.

Thanks to personal efforts on AIME's behalf by a few prominent members, the Institute once again led the way—this time in the first few weeks of the Member Gifts Campaign. But it is only a start. AIME members have a quota of $500,000 to raise. Vice President J. L. Gillson, with aid from Evan Just, Mike Haider, and O. B. J. Fraser, has organized the program. Joe Gillson will do his job, and from here out it will be up to us as members to do ours. I can do no better than quote Charles F. Kettering, Honorary Chairman of the Member Gifts Campaign for UET:

"The program is sound. It is timely. It merits your support."

"To you—my fellow engineers—I extend my personal endorsement of the project. I urge you to give, not only in dollars, but in service to the campaign."

This fall every Member and Associate Member living in the United States will be, or will have been, approached. When you receive the pledge card, you will have a rare chance to help build the engineering profession to its proper status in America and the world.—*R. A. Beals.*



Corrosion Resistance It is an immutable law of Nature that all things seek their most stable state. Nitroglycerine craves opportunity to explode back into passive water and gas vapor. Radium glows silently as it decays into lead. Metals yearn to return to their oxides.

Corrosion is simply the return of a metal to its most stable form. It's an electrochemical process that is generally speeded up by the presence of salts, acids and moisture—in fact, at humidities below 50% there is virtually no atmospheric corrosion of steel. There are six common ways to minimize corrosion: select the right steel, apply protective coatings, install cathodic protection devices, set up periodic cleaning procedures, control the corrosive environment, and use *design* techniques which reduce the likelihood of corrosion.

We have a record of one case where a manufacturer installed expensive piping to transport gaseous chemicals—overlooking the fact that ordinary carbon steel pipe would do the job just as well *if it were insulated* to prevent condensation of the chemicals inside the pipe. Sometimes a vessel is designed with great care so that it will hold a corrosive liquid, only to have the vessel attacked from the *outside* because the support brackets harbored pockets of moisture. And there are cases on record of stress corrosion failure because it was not recognized that stress relieving was necessary after cold working the metal.

Actual service records or true-to-life corrosion tests are the safest ways to judge a grade of steel, and you can often avoid the expense and time-consuming nature of making your own tests if you check first with United States Steel.

A corrosion problem that is new to you may be familiar to us, and we may be able to supply you with information that will solve your particular problem promptly.

Another good reason for coming to United States Steel is this: no matter what kind of steel you need, you're sure to find it among the vast range of USS Steels for Design. The final selection, of course, should be made by a skilled metallurgist. Our technical staff is always available to consult with you about your problems. United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

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USS **United States Steel**

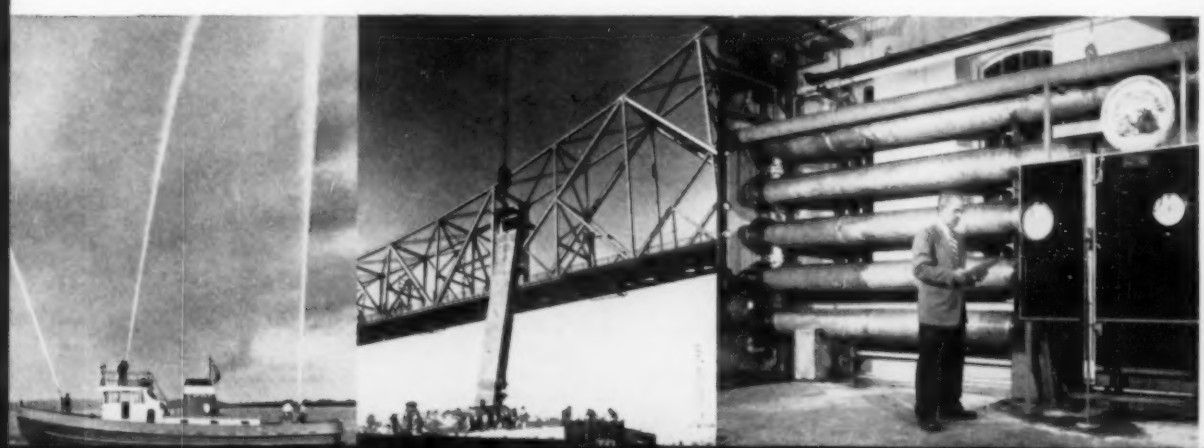
STEELS FOR DESIGN

Stainless Steel obstetrical forceps

Lower Left—Problem: The City of Pittsburgh wanted a trouble-free hull on their new, all-steel fireboat. Solution: Paasch Marine Service built the hull with ¼" USS COR-TEN High-Strength Low-Alloy Steel. Payoff: A light, strong hull that has four to six times the atmospheric corrosion resistance of carbon steel plus superior paint adherence.

Lower Middle—Problem: Combat corrosion in the new Carquinez Strait Bridge by designing smooth, welded members eliminating details vulnerable to corrosion. Solution: USS "T-1" Constructional Alloy Steel and USS TRI-TEN High-Strength Low-Alloy Steel, both weldable and both having superior resistance to atmospheric corrosion. Payoff: The smooth, welded framework will assure much lower maintenance costs than the annual $70,000 needed to paint and maintain the old, riveted bridge. (And a bonus advantage: "T-1" Steel's high yield strength permitted strong, lightweight design, saving $800,000 in over-all cost.)

Lower Right—Problem: Design a preheating unit for a textile plant to handle hot water with a highly corrosive caustic soda content. Solution: 19,000 lineal feet of Type 304 Stainless Steel tubing inside the Stainless shells. Payoff: Ludell Manufacturing Company predicts that the unit will last indefinitely.

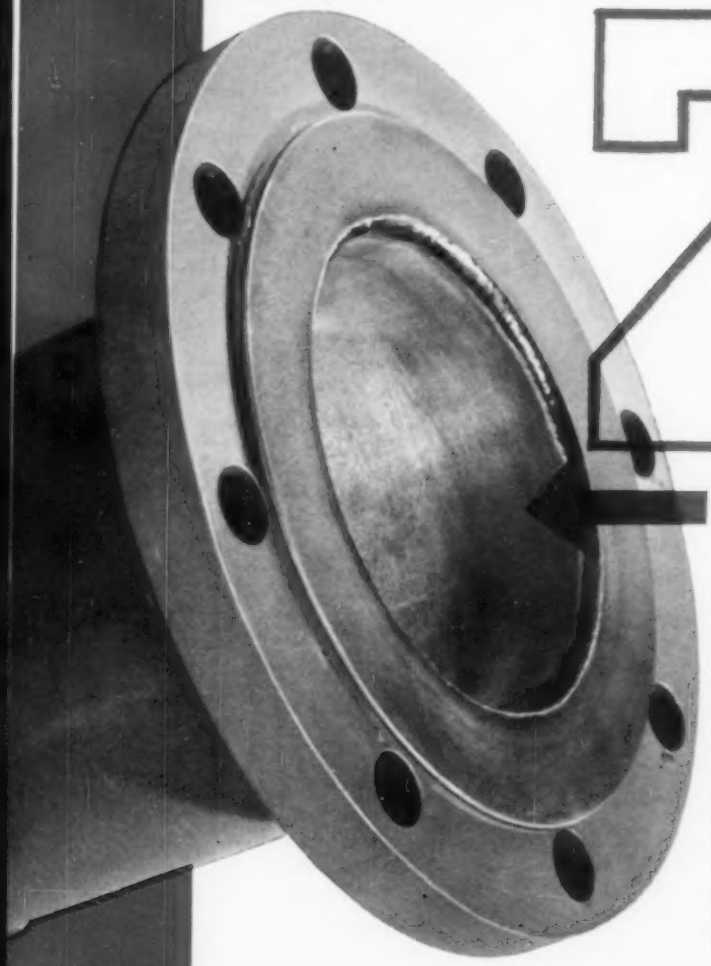


this flanged "T"....

another Carborundum Metals' engineering first

Zirconium lined T (6" diameter and 18" long) was manufactured for use in severe mineral acid service.

. . . fights corrosion with economy



Zr

on the inside

(mild steel on the outside)

Zirconium liners are now available for a variety of basic processing components such as "T's", columns, tanks and reaction vessels. These liners provide all the versatile corrosion-resistance and outstanding nuclear properties of zirconium at surprisingly low cost. Rapid advances in zirconium manufacturing and fabrication techniques offer greater savings for:

THE NUCLEAR INDUSTRY

Zirconium's low neutron absorption and corrosion-resistance to coolants permits more economical fuel applications in almost every reactor design.

THE CHEMICAL PROCESSING INDUSTRY

Dual resistance to corrosion... zirconium protects against either strong acids or caustics. Versatility means interchangeability and longer lasting system components.

Carborundum Metals' fully integrated zirconium facilities and its close working relations with leading fabricators gives you *one* experienced source for every need in zirconium... from sponge metal to ready-for-service components. Firm quotations and delivery dates can be made immediately on commercial or nuclear grade sponge and ingot, and also on welded or seamless zirconium tubing, zirconium sheet, strip, bar, rod and foil.

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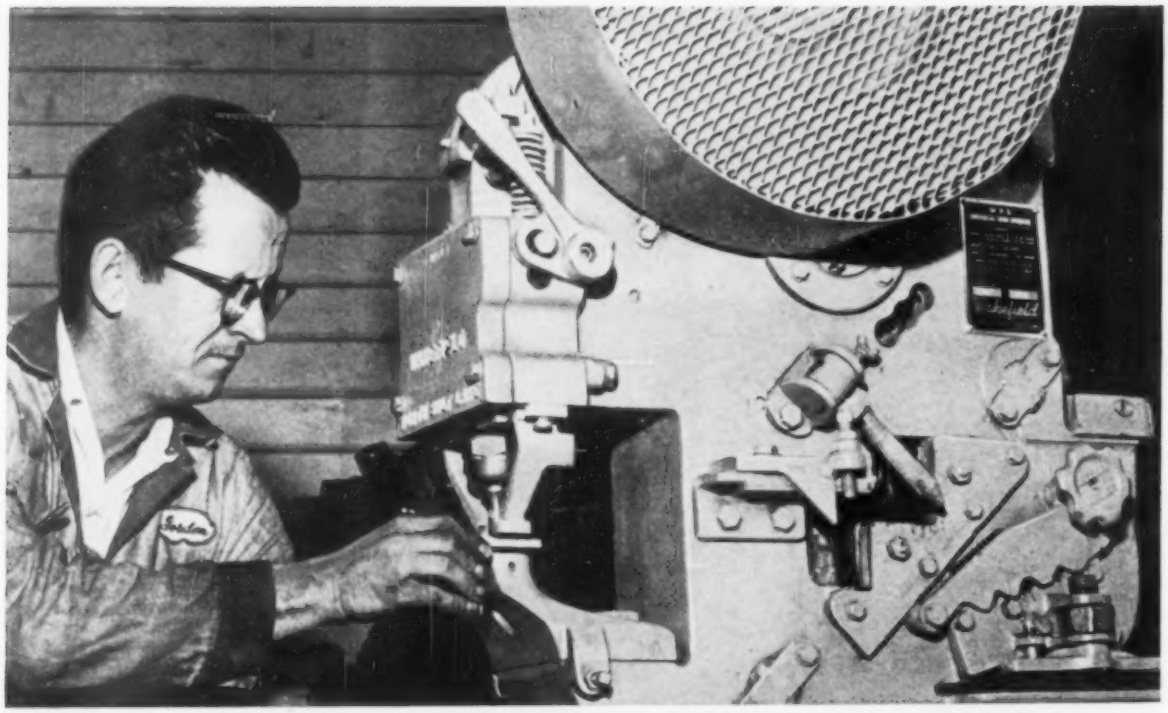
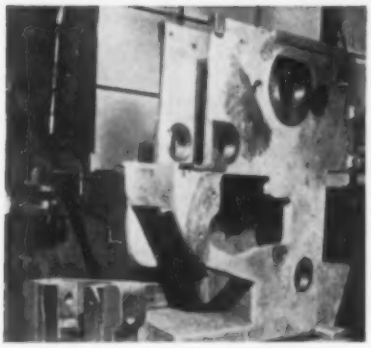
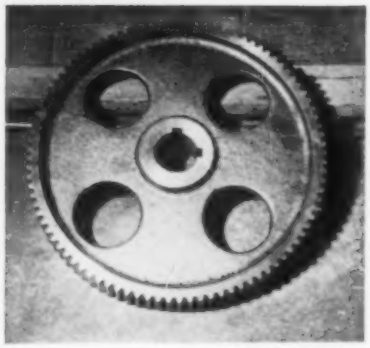
Production Pioneer of ZIRCONIUM

CARBORUNDUM

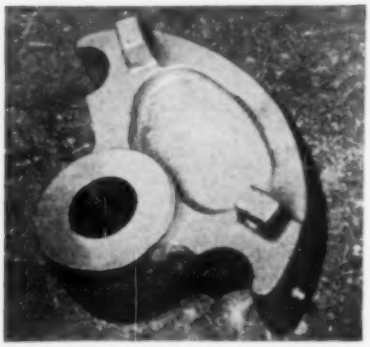




Cast frames with tensiles up to 200,000 . . . eliminate flame cutting of rolled sheet steel.



Cast gears that Brinnel to 475 . . . that withstand heavy loading even with ordinary lubricants.



Machine bearing surfaces right in the castings . . . eliminate bushings, without sacrificing service.

Build machines like this for less money ...the ductile iron way

Wakefield, Inc., of Salt Lake City, Utah, makes 95% of the cast parts for their "Iron Worker" portable mechanical press of ductile iron.

With ductile iron, they benefit two ways. First, they get the *process* economies of cast iron – good castability, machinability, moderate cost. Second, they gain many of the product advantages of steel – tensile strength of 73,000 to 80,000 psi, yield strength of 63,000 to 67,000 psi, good elastic modulus, excellent impact resistance. In addition, they get the excellent wear resistance of cast iron. Castings are supplied by Backman Foundry, licensed producers of ductile iron.

For more information about ductile iron castings, write for new 28-page Inco bulletin, "Ductile Iron Digest."

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ductile iron . . . the cast iron that can be twisted and bent.

Heavy elements in weighable amounts

The Second United Nations International Conference on the Peaceful Uses of Atomic Energy has announced that weighable amounts of Californium have been produced. S. G. Thompson, together with M. L. Muga and B. B. Cunningham, measured 0.06 micrograms of element 98 at the University of California at Berkeley last July. Also confirmed: reports that 0.023 micrograms of Berkelium were weighed in April. Chemical analysis is now underway.

Atoms For Peace conference

Beryllium may, under certain conditions, alloy with uranium and its compounds. As a result, it may not be an entirely compatible material to use in fuel elements. Such was one of the major metallurgical revelations reported at the Atoms For Peace conference in Geneva. The conference report and review of outstanding metallurgical papers is found on p. 711 of this issue.

Integrated power reactor system

Argonne National Laboratory displayed models of the first completely integrated power reactor system operating on a closed fuel cycle at the Atoms For Peace conference. The Experimental Breeder Reactor (EBR-II), under construction at AEC's National Reactor Testing Station near Idaho Falls, Idaho, will start the nuclear chain reaction in its uranium core in 1960, according to present plans. Termed a completely integrated reactor system because it will have a fuel reprocessing and refabrication facility, in addition to the reactor, heat transfer systems, and steam-electric plant, the breeder-type reactor developed by Argonne scientists is regarded as promising because it produces more fissionable material than is consumed in the reactor. EBR-II's reactor will be unmoderated and sodium cooled.

Tests of Fuel Elements

A report by General Electric's R. S. Paul and Argonne's W. J. McGonnagle, recently released in Geneva, reveals the stringent nondestructive tests applied to fuel for nuclear reactors. Thousands of fuel elements used every year, states the report, are inspected and tested with the aid of sound vibrations, ultrasonic waves, eddy currents, X-rays, and gamma rays. Ultrasonic waves measure the size and determine the orientation of crystals in the uranium fuel pieces. They also find flaws in the metal and in the aluminum jacket that encloses each fuel element. Eddy currents measure variations in thickness of the jackets. X-rays or gamma-rays probe the physical characteristics of fuel elements to determine the uniformity and distribution of fuel contents, the thickness of claddings, and the integrity of welds.

Each fuel element must be as nearly perfect as possible . . . no holes or cracks in the aluminum jacket . . . no flaws that might develop into openings during irradiation. The uranium itself must be solid and flawless to withstand the stresses and strains that occur in the metal while in an operating reactor. Referring to methods used at Hanford, Argonne, Oak Ridge, and Los Alamos, the report noted that much of the handling and processing of fuel elements between and through the various tests has been automated.

FIFTH VOLUME

ON

NUCLEAR METALLURGY

All the Papers at Symposia on
Ceramic Base Elements
and
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October 29, 1958

(AIME Fall Meeting of The Metallurgical Society, Carter Hotel, Cleveland, Ohio)

Fabrication of Ceramic Fuel Elements by Swaging	by D. R. Stenquist and R. J. Anicetti
Pressure Bonding of Zircaloy-Clad Flat-Plate Uranium-Dioxide Fuel Elements	by S. J. Paprocki, E. S. Hodge, and D. C. Carmichael
Fabrication of Aluminum Plate-Type Elements Containing Uranium Dioxide as the Fuel	by S. I. Megeff and J. L. Zambrow
Stainless Steel-Uranium Dioxide Fuel Components for the Army Package Power Reactor	by J. E. Cunningham and R. J. Beaver
Preparation of Zirconium-Base Dispersion Fuels	by A. P. Beard and R. N. Honeyman
Fabrication and Properties of Uranium-Zirconium Hydride Fuel Elements for Triga Reactors	by W. P. Wallace, M. T. Simnad, and B. Turovlin
Silicon-Modified Uranium-Aluminum Alloys for Foreign Reactor Applications	by W. C. Thurber and R. J. Beaver
Fabrication of Iron-Aluminum-Chromium Fuel Plates	by Blake King, J. Neri, and F. G. Tate
Fabrication of Zircaloy-2 Clad Uranium—12 Wt. Pct. Molybdenum Fuel Rods	by J. G. Goodwin, R. W. Tombaugh, E. L. Richards, and F. R. Lorenz
Manufacture of EBR-I, Mark III Fuel and Blanket Rods	by R. A. Noland, N. J. Carson, C. C. Stone, F. D. McCuaig, and R. E. Macherey

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Volumes 1, 2, 3, and 4 will be available at the Registration Desk, or can be ordered by mail. Volumes 1, 2, and 3 are priced at $3.75 (AIME members: $2.50), and Volume 4 is priced at $7.00 (AIME members: $5.00.)

Books

(Continued from page 693)

the theory of semiconductors. This is followed by units on the measurement of semiconductor parameters; the theory of the p-n junction; junction and point-contact transistors; measurement of transistor parameters; manufacture of transistors; silicon and other transistor materials.

Engineering Problems Manual, Fifth Edition, by Forest C. Dana and Lawrence R. Hillyard, *McGraw-Hill Book Co. Inc.*, 402 pp., $11.00, 1958—The authors main purpose is the development through the utilization of the principles of physics and mechanics, of a systematic approach to the analysis of practical engineering problems and the numerical calculations involved in their solutions. This edition includes additional material on compound interest and a new chapter on the art of problem solving. •

Electronic Semiconductors, (Translated from the second German edition by D. A. Jenny and others) by Eberhard Spenke, *McGraw-Hill Book Co. Inc.*, 402 pp., $11.00, 1958—An advanced study of the physics of semiconductors. The book begins with fundamental concepts, including a detailed description of the operation of crystal rectifiers and the physics of crystal amplifiers, and proceeds to such topics as quantum mechanics of the hydrogen molecule, the band model, Fermi statistics of electrons in a crystal, imperfection

equilibria, and boundary layers in semiconductors. The Translators have added problems to each chapter and a new section on junction capacitance. •

Transistor Technology, Vol. I, by members of the Technical Staff of Bell Telephone Laboratories, *D. Van Nostrand Co. Inc.*, 120 Alexander St., Princeton, N. J., 661 pp., $7.50, 1958—An extensive study dealing with the theory and fabrication of germanium transistors. This volume, which is the first of a series, presents the basic framework and covers the technology of germanium materials, preparation of single crystals, principles of device fabrication, principles of transistor performance characterization, and transistor reliability. An appendix gives definitions and letter symbols relating to semiconductors.

Applied Statistics For Engineers, by William Volk, *McGraw-Hill Book Co. Inc.*, 354 pp, $9.50, 1958.—Concerned with the treatment of engineering data for correlation, precision, and analysis of experimental factors. It emphasizes engineering applications rather than theory and provides a number of illustrative examples. A review of probability theory and frequency distribution is included, along with detailed discussions of curvilinear correlation, the analysis of variance, and the interpretation of the analysis of variance. •

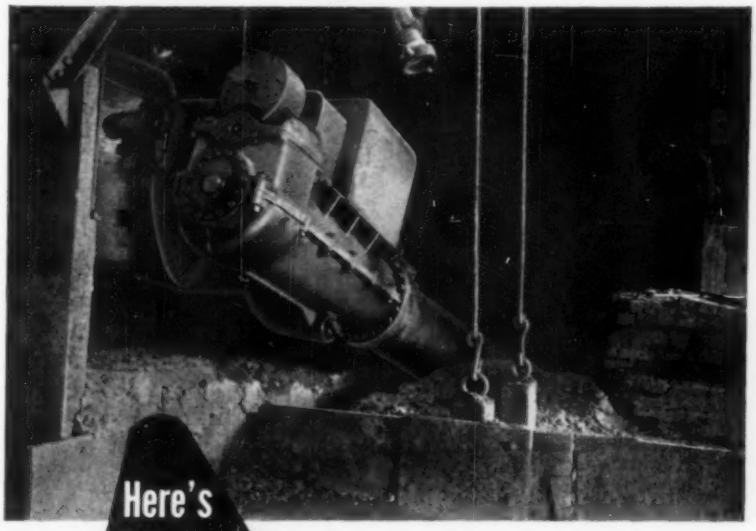
Nuclear Reactor Experiments, by the staff of Argonne National Laboratory, *D. Van Nostrand Co. Inc.*, 120 Alexander St., Princeton, N. J., 480 pp., $6.75, 1958.—Problems relating to design, construction, and operation of nuclear reactors are outlined with details of equipment and experiments. Areas included are nuclear radiation detection, moderator and subcritical assemblies, cross sections, operating reactors and their characteristics, heat removal from a reactor, corrosion and radiation effects, fuel preparation, and separation processes.

Metals, special technical publication No. 196, by the *American Society for Testing Materials*, 1916 Race St., Philadelphia 3, Pa., 175 pp., $4.50, 1958.—Twelve papers dealing with corrosion, fatigue, and strength properties of metals. Specifically, they cover shotpeening, effect of forming on properties, axial stress fatigue, and results of studies on steels, aluminum, magnesium, and beryllium copper. •

The Metal Molybdenum, edited by Julius J. Harwood, *American Society for Metals*, 7301 Euclid Ave., Cleveland 3, Ohio, 696 pp., $12.50, 1958.—Proceedings of a symposium sponsored by the Office of Naval Research

(Continued on page 708)

180 Bailey CLAY GUNS IN CONTINUOUS SERVICE



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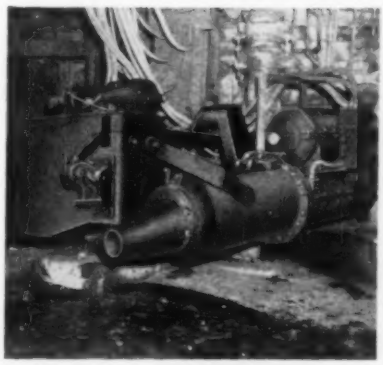

With clay pressures of 600 psi, these guns provide ample power for plugging and maintaining long tapping holes. A unique mounting and operating system assures fast and accurate positioning with the ultimate in safety.

Bailey Electric Plunger Clay Guns are adaptable to both blast furnaces and large electric furnaces.

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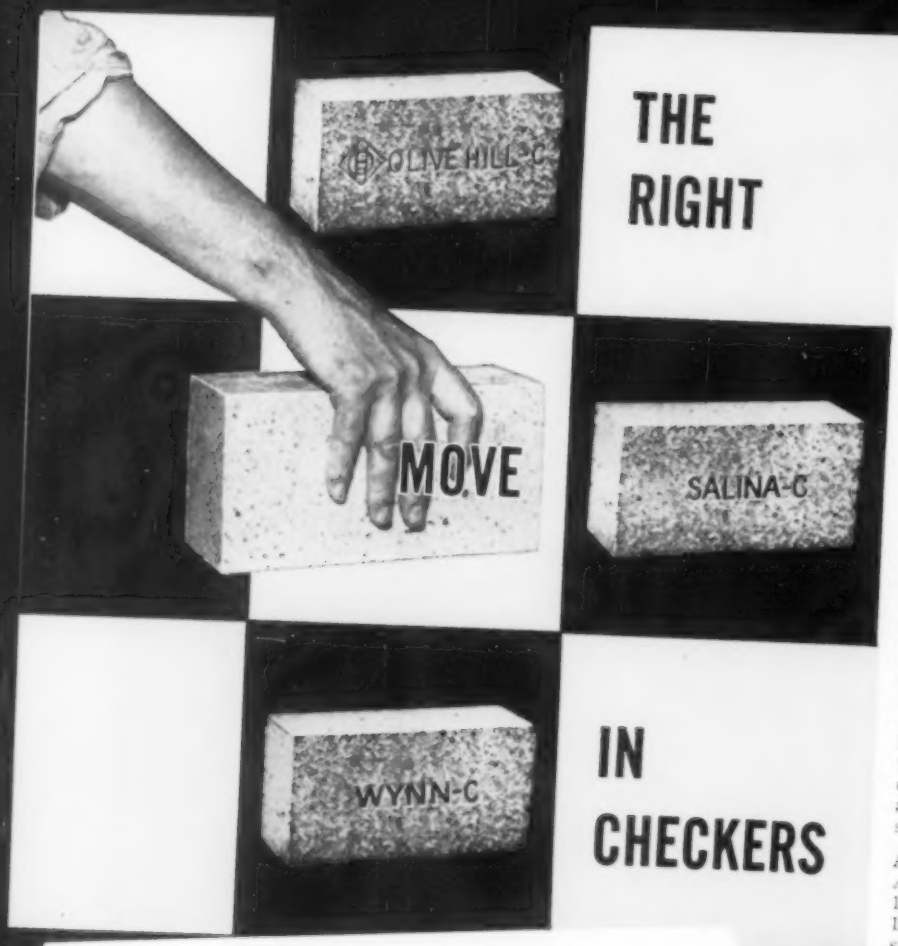

THE RIGHT

IN CHECKERS

General Refractories offers **superior** high duty fireclay checker brick; possessing all four properties recognized as the criteria for long life in regenerator chambers — high density, low porosity, high strength and refractoriness.

High density and low porosity are needed to insure volume stability, optimum heat transfer and minimum penetration of flux-bearing gases. High refractoriness, coupled with these other properties, is needed to withstand the temperatures prevalent in most regenerator chambers.

Any one of these properties by itself cannot describe an excellent checker. It is the combination of all these properties in one product that produces a superior checker brick.

GREFCO checker brick possess *all* these attributes. Manufactured from select, highly refractory fire clays; by GREFCO's unique double-tempering process; pressed in special dual-action, deairing power presses, fired to high temperature in tunnel kilns; and given a final rigid inspection for accurate size and quality; General Refractories' "C" brands are superior checkers.

Surely, "THE RIGHT MOVE IN CHECKERS" is to — GREFCO!

WRITE FOR NEW LITERATURE ON CHECKER BRICKS

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Books

(Continued from page 707)

at Detroit in 1956. The papers represent a survey of the present status of molybdenum technology, particularly in relation to the use of molybdenum at high temperatures. Aspects studied include molybdenum as a structural material preparation and fabrication, metallurgy, alloys for gas turbine applications, and European developments. •

A Handbook of Lattice Spacings and Structures of Metals and Alloys, by W. B. Pearson, *Pergamon Press,* 122 E. 58 St., New York 22, N. Y., 1044 pp., $38.00, 1958.—A reference work on the structure and lattice spacings of binary and ternary alloys. Part one is a general introduction to the x-ray investigation of metals and alloys with emphasis on the use of structure determination and lattice spacing measurements to provide information on the physical state of metals and alloys, particularly equilibrium diagram determination. Part two is a compilation and assessment of published x-ray work on metals and alloys in equilibrium with alloy systems listed in alphabetical order.

ASTM Standards on Iron Casting, *American Soc. for Testing Materials,* 1916 Race St., Philadelphia 3, Pa., 158 pp., $2.75, 1957.—Brings together standards and tentative methods of test as well as specifications relating to iron castings. Includes information on pig iron, grey iron castings, cast iron pipe, nodular iron castings, malleable iron castings, and welding rods and electrodes. •

Education

(Continued from page 694)

Chairman, or Dr. D.K. Felbeck, Secretary, Conference on Fracture, National Academy of Sciences-National Research Council, Washington, D. C.

FUTURES IN STEEL

Bethlehem Steel Co. is now offering a new 28-min., 16 mm color and sound film, *Futures in Steel,* available for showing to groups of students, faculty, placement directors, guidance counsellors, and other persons interested in careers for young men.

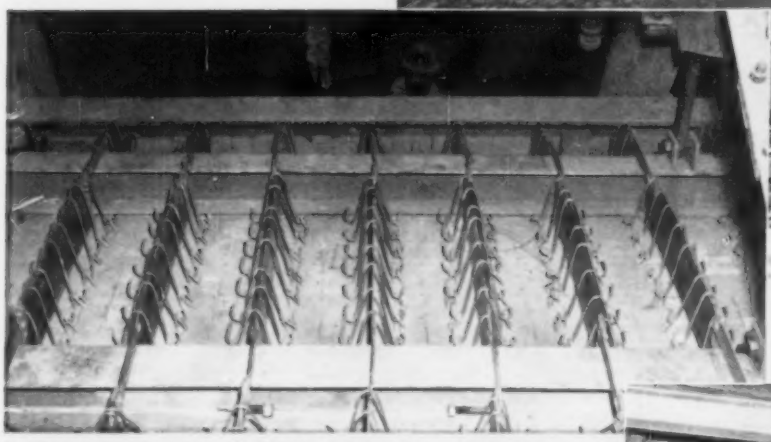
The movie thoroughly explores today's basic steel industry, beginning first with a glimpse of early American ironmaking, and then deals with modern steelmaking. The theme portrays men and their accomplishments.

Bethlehem Steel films are distributed by *Modern Talking Picture Service, 3 East 54th Street, New York 22, N. Y.*

GREFCO

SALUTES...

Interior of Weirton-designed "All-Basic" furnace, with roof of STEELKLAD 40-EE "Tab" brick.



Exterior of "All-Basic" Roof of Weirton-designed furnace, using STEELKLAD 40-EE "Tab" brick.

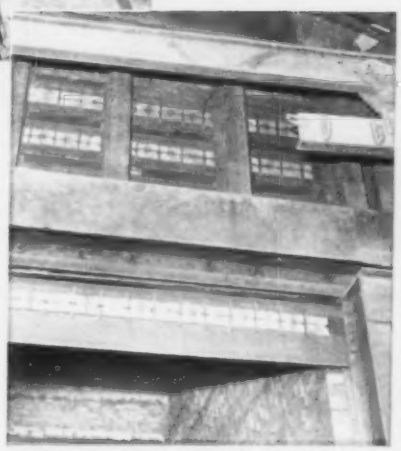
WEIRTON STEEL

for "All-Basic" Steelmaking

Weirton Steel Company, a division of the National Steel Corporation, is one of the leaders in technological steelmaking advances. Part of this leadership is shown by these photographs of new "All-Basic" furnace installations at Weirton, including one of the largest open hearth furnaces on the American Continents.

These "All-Basic" furnace installations, especially tailored and designed by Weirton for ultimate economy and ease of construction, are built with GREFCO basic brick. All suspended construction utilizes either "Tab" or "Ferroclip" hangers, and all the brick are "STEELKLAD-A", "STEELKLAD-40" or "STEELKLAD 40-EE".

GREFCO is proud to have contributed to these notable advances in open hearth furnace construction.



View of Basic End showing pit side wall above slag pocket seal. Weirton-designed construction using GREFCO STEELKLAD-40 "Ferroclip" brick.

Detail of chill wall construction in Basic End designed by Weirton, using GREFCO STEELKLAD-40 "Tab" brick.

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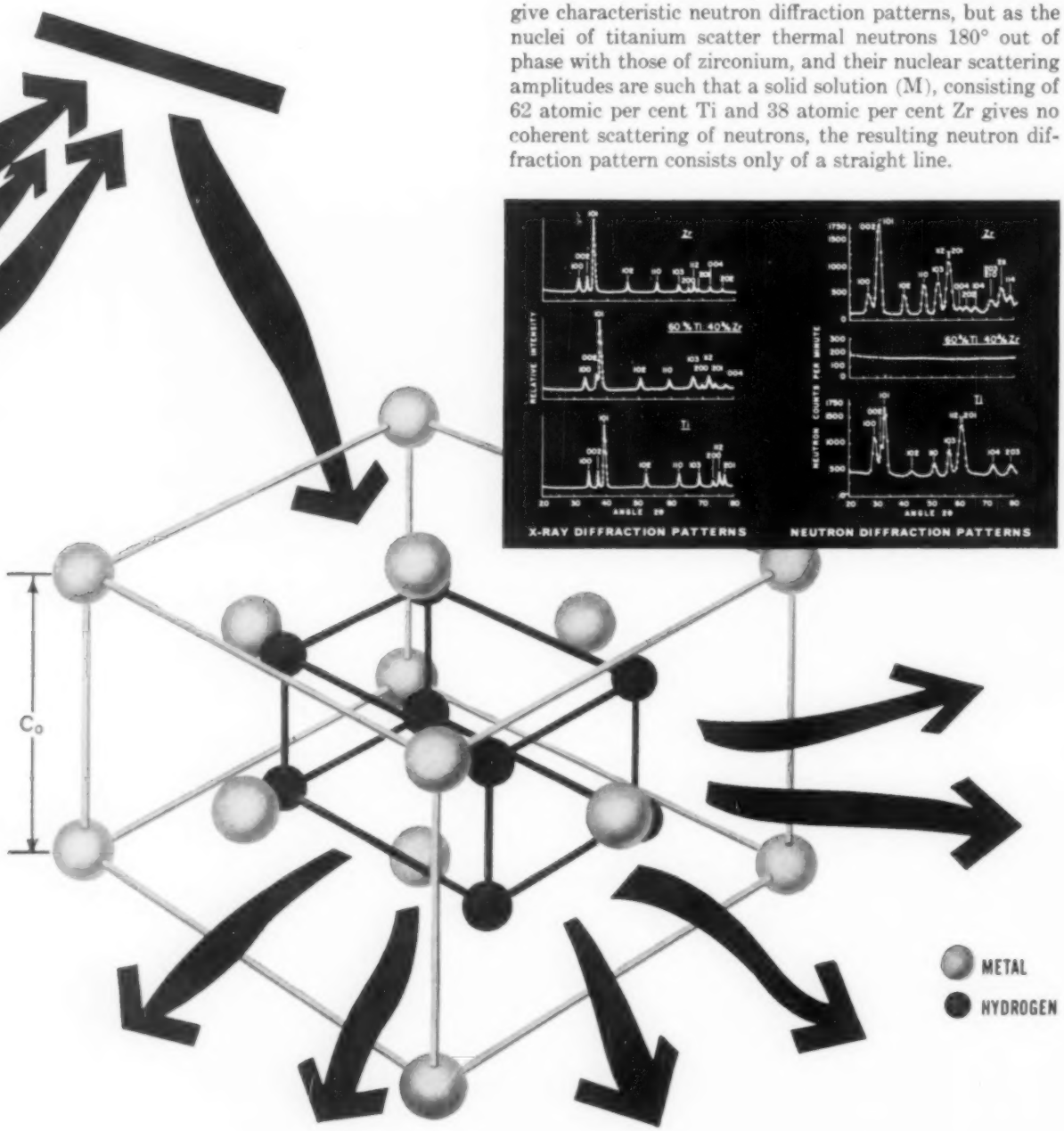
DETERMINING SOLID STRUCTURE BY NEUTRON DIFFRACTION

Titanium and zirconium, and their solid solutions give similar x-ray diffraction patterns. These two metals also give characteristic neutron diffraction patterns, but as the nuclei of titanium scatter thermal neutrons 180° out of phase with those of zirconium, and their nuclear scattering amplitudes are such that a solid solution (M), consisting of 62 atomic per cent Ti and 38 atomic per cent Zr gives no coherent scattering of neutrons, the resulting neutron diffraction pattern consists only of a straight line.



When a hydride of the solid solution (MH_2) is studied by neutron diffraction patterns, one observes reflections that result from scattering by hydrogen atoms only. This makes it possible to locate uniquely the positions of hydrogen atoms in such crystal structure matrices.

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GENEVA ATOMS-FOR-PEACE FEATURES FISSION, FUSION

A Staff-written Summary

"An unquestioned success" is the label applied by Under-Secretary Ralph J. Bunche to the Second United Nations' International Conference on the Peaceful Uses of Atomic Energy. Thermonuclear (fusion) reactions, atomic physics, and advancing reactor technology proved to be of considerable interest to 6300 participants.

IN enthusiastic perpetuation of an idea and an ideal set forth by President Eisenhower in his famous "Atoms for Peace" speech before the UN General Assembly in 1953, sixty-nine nations convened recently at the Second United Nations' International Conference on the Peaceful Uses of Atomic Energy. The meeting, held in Geneva from September 1 to 13, was similar to, but more extensive than the first such conference in 1955. The attendance of 6300 delegates was more than double the 3000 figure of the first gathering, as was the number of papers submitted, totaling nearly 2200 this year, after withdrawals. The location of the meeting was the Palais de Nations on Lake Geneva.

The conference sessions, 77 in number, were distributed between general sessions and five series of parallel sessions based on general fields of interest to various delegates. The fields covered by the parallel series were: fusion and nuclear physics, reactors, chemistry, isotopes and health and safety problems, and raw materials supply and metallurgy.

The general session ranged over many facets of nuclear energy, including such topics as the possibility of controlled fusion, the use of nuclear energy for purposes other than generation of electricity, supply and training of technical personnel, and recent developments in international collaboration.

Interest in the first of these topics, the possibility

Some of the 5000 scientists and observers of the Second UN International Conference on the Peaceful Uses of Atomic Energy attending a session in the Assembly Hall of the Palais des Nations in Geneva. Courtesy United Nations.

of controlled fusion, ran high throughout the conference. The fusion reaction—responsible for the energy of the sun and the basis of the hydrogen bomb—is the one which occurs when atomic nuclei collide, and fuse, releasing large amounts of energy. The problems involved are those of enclosing and stabilizing the hot electrically-charged gas (known as plasma) which contains the nuclei to be fused. The general topic of controlled fusion is a new one at these conferences. At the time of the first meeting, all information pertaining to it was secret. Restrictions have been relaxed gradually by various countries, shortly after the first conference, and it was just before the opening of this meeting that information on many current thermonuclear projects was released for discussion. Frances Perrin, of France, President of the conference, described papers on the subject as "by far the most striking revelation" of the meeting. He estimated that about ten years will be needed to develop efficient apparatus. It will be even longer before industrial installations appear, of course.

CERN confirms particle theory

Nuclear physics also came in for consideration when CERN, the European Organization for Nuclear Research, announced that experiments at its new experimental center had confirmed the exceptional reaction, long predicted on the basis of nuclear theory, by which pions disintegrate directly into electrons and neutrinos without passing through the mu meson stage. (A complete description of CERN and its present and proposed facilities will be found on page 717 of this issue.)

Exhibit draws 100,000

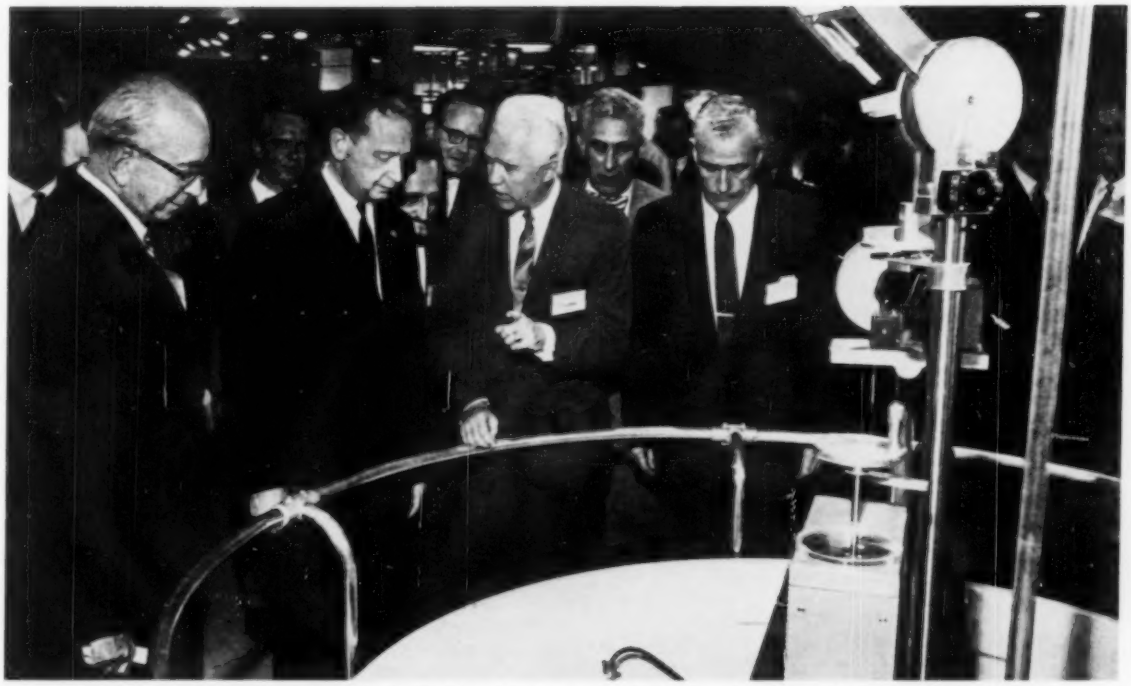
In addition to the conference itself, an atomic exhibition was organized and held in conjunction with the gathering in a temporary building erected for this purpose on the grounds of the Palais des Nations. Twenty nations participated, as well as CERN and the Joint Institute for Nuclear Research at Dubnacma, USSR. Here, as in the conference, interest in controlled fusion dominated. Indeed, 20 pct of the exhibit floor space was devoted to this subject. On display were such thermonuclear devices as the UK's *Zeta*, the *Stellarator, Pyrotron,* and *DCX* of the US, and a Soviet *toroidal chamber.* Accompanying the controlled fusion exhibits were visual presentations relating to these other topics of interest: latest uses of radioisotopes in medicine, agriculture, and industry; expanding use of nuclear fission reactors for producing heat and electricity.

A General Atomic TRIGA reactor was installed in the exhibit hall and operated during the conference to provide short-lived isotopes for the US Life Sciences exhibit.

Twenty nations participated in the exhibit, and attendance, composed of delegates and the general public, exceeded 100,000 in the two weeks of operation. At the first conference in 1955, nine nations maintained exhibits.

In discussing plans for the next conference, President Perrin commented that world activity in atomic energy appears to be doubling every three years. He is in favor of a longer interval between conferences, possibly four years rather than three, so that the excessive effort required in their preparation might be expended less frequently.

Upon reviewing the wealth of titles in the conference, one is immediately impressed by the extreme variety of types of papers presented at this meeting. Here is much more than a technical meeting on atomic energy. The technical aspects have been rather well covered, to be sure, but so have questions of personnel training, new applications of nuclear energy, and the finer points of well-established applications. With the intention of illustrat-



Admiral L. Strauss (left), Head of the U. S. delegation to the Conference, and UN Secretary-General Dag Hammarskjold, among other officials, being shown the Triga reactor in the US exhibit. Courtesy United Nations.

ing the variety of subjects discussed at Geneva, the following abstracts have been selected as having a particularly high level of interest to metallurgists.

Atomic energy in steelmaking

Some Practical Aspects of the Use of Nuclear Energy in Steel Industry, by P. Bergognan, R. Bourion, R. Gibrat of France.

Considering the number of items in the heat balance for producing pig iron, numerous applications of nuclear energy in this process are suggested. One might even envision a whole new process and variations to accomplish the same end. The possibilities are, thus, many and varied.

The use of nuclear energy in the steel industry also creates numerous practical difficulties, since present operations are based on years of experience. May not the radiation hazard necessitate security measures the cost of which cost might prove prohibitive? What about the possibility of dangerous radioactivity in the metal and gases produced?

This paper attempts to answer these questions without recommending a complete revision of steel industry principles. Thus, in a 1000 ton per day blast furnace, suppose that a reactor is used to heat the blast, thus eliminating the cowpers. Such an application is prompted by two considerations: heating the blast consumes large quantities of heat, and this is the application with the lowest temperature requirement (426°F). Even this temperature is high enough to create serious problems in reactor construction, however at the present state of development, this is the only realistic application to consider.

The reactor, of 50 megawatt capacity, is expected to supply air at high temperature and low pressure (just under 3 atm). Since the pressure is not conducive to good heat transfer, the volume of the reactor must be large. The fuel employed is slightly enriched UO_2, canned with stainless steel and using a graphite moderator with corrosion-resistant coating.

Air containing fine particles becomes radioactive when subjected to the neutron flux in the reactor. Since the reactor is shielded, this air represents the sole radiation hazard. In this air, argon 41, with a half-life of 1.8 hr, represents the highest level of radioactivity to be encountered. In the vicinity of pipes carrying the blast, this gives a radiation intensity of about 1 milliroentgen per hr. This is a permissible level, eliminating the need for shielding or keeping personnel away from the pipes. This is also true in the case of the gas lines leaving the furnace.

There is serious danger in inhaling the radioactive gases, however. In the case of gases leaving the blast furnace, it has been shown that the maximum concentrations correspond to those dictated by the carbon monoxide hazard. Thus, measures to control the latter hazard also suffice to protect workers from radioactivity. In the case of the heated air, however, such is not the case. In conventional operations, air leaks present no hazard, and no attempts are made to eliminate them. But with a reactor in operation, it is as important to eliminate air leaks as gas leaks. Because of the high air temperature, however, it is more difficult; therefore, it will be necessary to develop air-tight equipment for this application.

If blast-furnace gas is treated in a by-product plant or sold to power companies, exhaust gases will be radioactive. Precautions, such as those employed in some plutonium production reactors, may be necessary. If the gas is used elsewhere in the plant, such as in heating furnaces, the problem of *hot* exhausts will arise anew.

An economic study of this project indicates that under conditions that exist in the French steel industry and on the basis of published prices for fissionable material, the cost of nuclear heat may be

lower than that obtained by conventional means, even with the amount of fuel needed to operate such a large-size reactor. The cost of a large quantity of fuel is offset by the long fueling cycle, which could conceivably approach ten years.

Fuel elements

The Manufacture of Fuel Elements for the Dounreay Fast Reactor, by C. J. Turner, L. R. Williams of the UK.

An outline is given of the fast reactor and the fundamental considerations underlying the design of the fuel element. One of the major factors is the embodiment of a safety principle which, in the event of a power excursion, permits the release of highly enriched uranium from the fuel elements in a controlled manner so as to ensure that the assembly becomes subcritical. The initial fuel element design was based on the use of an outer columbium tube and a vanadium inner tube, the highly enriched uranium being contained between these two in the form of annular sections. This design has remained substantially unaltered throughout the development period.

An assessment of the complex problems associated with the production of such a fuel element is given. These included full metallurgical development of the two metals: columbium and vanadium.

A description of the development programs associated with the production of the fuel, canning materials and assembly techniques follows, together with an account of the development of inspection and testing techniques for both the individual components and the completed fuel element.

Concurrently with the later stages of the development program, it was necessary to construct a fuel component production line, together with an assembly line for the actual fuel elements to be used in the reactor. An outline of the facility is given, and some of the more interesting items of equipment are described in detail.

The paper concludes with a general account of the planning of the work and an indication of the effort involved in terms of scientific man-power and costs.

The Manufacture of Internally Cooled Pressurized-Tube Elements of Metallic Uranium by a Zone Melting Process, by P. Sulzer and E. Bodmer of Switzerland.

The pressure vessel of a heterogeneous pressurized-water reactor plant can be replaced by a suitable pressurized tube system. The cooling liquid flows under pressure through internally cooled, cylindrical fuel elements, which themselves form the pressurized tube system. The moderator can, therefore, be kept under normal pressure conditions at a completely low temperature. The internal pressurized tube, which is also designed as a protective sheath, is dimensioned to take the whole pressure required to prevent vapor formation.

Zircaloy-2 appears to satisfy the requirements for the manufacture of pressurized-tube elements. A short period of contact between molten uranium and solid Zircaloy-2 leads to mutual diffusion and, thus, to the necessary metallic bond of the two metals.

Basically, there are two methods of manufacturing pressurized-tube elements by using molten uranium: continuous casting and zone melting. Zone melting permits the manufacture of pressurized-tube elements with simple equipment.

To start the manufacture of tubes, pre-cast uranium cylinders are fitted over tubes of Zircaloy-2. The insertion of drilled plates of graphite between the uranium cylinders, helps to prevent segregation (in the case of uranium alloys) during the zone melting process. Later, when the reactor is in service, these serve to cushion the swelling of the uranium to a certain extent.

The element, thus constituted, is encased in a suitable permanent mold and is then subjected, under vacuum conditions, to an inductive zone melting process from bottom to top. The rate of feed and the inductive input are so regulated that the uranium, as the molten phase, is welded to the Zircaloy-2 in the shortest possible time.

The fuel element thus produced has a cast uranium structure which has been recognized as advantageous. The metallic bond between uranium and Zircaloy-2 is in no way inferior in mechanical properties and corrosion resistance to the bonds obtained by other methods.

Irradiation effects

Effects of Neutron Irradiation on Mechanical Properties of Ferritic Steels and Irons by L. P. Trudeau of Canada.

The effect of fast-neutron irradiation at 50°C to 70°C on the mechanical properties of some ferritic steels and irons has been investigated with particular emphasis on determining the correlation between the magnitude of irradiation damage and the composition and microstructure. Impact energy transition curves and tensile-test results are reported for sub-sized specimens; the correlation between results for sub-sized samples and those for full sized samples is given for unirradiated material.

US Navy HY65 alloy (a Ni-Mo-V-Cu low-carbon steel) has been examined in three conditions: a) normalized and tempered, b) austempered and tempered, and c) quenched and tempered. The third condition was found to be the least susceptible to irradiation damage; this result may have been influenced by the higher initial hardness which resulted from this treatment.

Samples of five ferrites (carbon contents of 0.013 to 0.024 pct) containing 3.2 pct Ni, 1.5 pct Mn, 1.0 pct Cr, and 0.5 pct Mo have been irradiated for different times. Although the nickel-and manganese-bearing ferrites initially had much lower brittle-ductile transition temperatures than the other alloys, after irradiation the brittle-ductile transition temperatures of these materials approached that of unalloyed ferrite. However, it should be noted that the tensile strengths of the nickel and manganese ferrites were considerably higher than those of the unalloyed ferrite, both before and after irradiation. The increase in yield strength for a given irradiation was about 10 pct higher for nickel than for manganese ferrites; in turn, the value for the latter material was about 10 pct higher than for unalloyed and chromium ferrites. The tensile properties of the molybdenum ferrite were least affected by irradiation. This variation in the increase in mechanical properties brought about by irradiation is considered to account, at least partly, for the fact that, after irradiation, the brittle-ductile transition temperatures of the nickel and manganese ferrites are close to that of unalloyed ferrite.

The effect of irradiation on the brittle-ductile transition temperature has been found to be mark-

edly dependent upon the type of steel. For example, an increase of about 125°C was found for the as-hot-rolled ASTM A201 mild steel after an integrated flux of about 1.2×10^{20} nvt with neutrons energies above 500 ev, whereas for normalized US Navy HY 65 alloy, the increase was 96°C after an irradiation of 1.0×10^{20} nvt. Annealing of irradiated ASTM A201 mild steel produced no recovery at 260°C, but considerable recovery at 335°C.

Fuel processing

Nuclear Fuel Processing Plants; A Survey of Design and Operational Practices, by J. L. Schwennesen of the US.

The diversified expansion of the nuclear reactor field has occasioned a corresponding increase in the size and scope of irradiated fuel reprocessing responsibilities. Reactor fuel processing has now become a very diverse and large-scale activity.

Original processing plants (because of the stress of wartime years) were designed and constructed on a very hurried—and necessarily conservative—basis, since little or no counterpart existed in previous experience. How has the evolution of new process concepts, the development of novel equipment components especially designed or developed for this field, and the availability of a considerable backlog of experience modified the bases for processing plant design and operation? It now seems appropriate, after some 15 years of experience, to review past progress in this field and to consider the possible or probable features of plants which may be constructed in the near future.

This report presents a detailed survey of plant design philosophy, engineering, and operational control features of US fuel processing plants. It does not discuss technological or process aspects, since these are thoroughly covered elsewhere.

An attempt is made to categorize plant features with plant objectives to properly qualify the information presented. US attitudes with respect to the design and operation of new plants are generalized and discussed in terms of the specific purposes of new plants.

Matters discussed within the framework described in the two paragraphs above include:

1. A very brief comparison of perhaps the most basic element of plant design, e.g. *remote* vs *direct* maintenance philosophy. Some of the factors involved in making a choice between the two methods are outlined and the evolution of opinion on the subject is discussed briefly.
2. Structural bases for plant design, segregation (arrangement) of plant equipment, commercial vs *special* equipment, equipment fabrication tolerances (and costs), location aspects, (and resulting costs) for supporting facilities such as control laboratories, *sparing* philosophy for process equipment, design for nuclear safety, bases for shielding design, etc.
3. The evolution of opinion and experience with respect to use of mechanical equipment, such as pumps, valves, motors, pulsers, agitators, etc., in radioactive services. New developments in this field are discussed together with the important characteristics of such equipment.
4. The evolution of the *flexibility factor* as an important consideration in plant design. With the rapid advancement of processing technology and resulting potential for engineering or process innovations, the ability to build in flexibility initially may be an important factor in plant design. Examples are cited.
5. Changes in plant, operational-control philosophy as a result of experience, new process or equipment innovations, etc. Matters discussed include staffing philosophy (type and quantity of manpower) and the important progress made in reducing costs of process control by analytical and instrumentation techniques.

All of the above factors are integrated with respect to their place in the economic picture for future plants. The prospect for achieving significant reductions in capital and operating costs is an important factor in developing the economics of the processing portion of the total fuel cycle.

Hanford Operation

Design and Operation of Hanford's Metallurgical Facilities by O. J. Wick and I. D. Thomas of the US.

A brief history of Hanford's metallurgical research and development facilities, which began operation in 1951, is presented. Since startup, the laboratory has expanded considerably to keep pace with an enlarged fabrication development program. An active plutonium fuels development program at Hanford was started in 1957 and a development pilot plant was designed for the fabrication of a wide variety of experimental plutonium fuels. The latter facility is now under construction and will be in the limited operation by 1959.

The handling of plutonium in large quantities is discussed from the standpoint of precautions required in addition to those needed for a research operation. Large scale fabrication development work is of such a nature that an occasional glove rupture or other incident must be expected. Design of facilities at Hanford to minimize the spread of uncontrolled contamination and to facilitate decontamination procedures include: 1) Compartmentation of the laboratory area; 2) flow of laboratory air from areas of low contamination potential to those of high potential; 3) down-draft air flow to floor exhausts below glove boxes and hood; 4) provisions for static inert gas or dry air atmospheres

German scientists discuss with the Russians their model Ogra, an experimental machine for controlling thermo-nuclear reactions. Courtesy United Nations.

in glove boxes with adequate exhaust capacity to provide a minimum flow of 120 lineal ft per min into hoods through openings such as ruptured gloves, air locks, etc.

The operational philosophy is given for the prevention of the accumulation of a critical mass which cannot be completely guaranteed by the design of a versatile developmental facility. Thorough training of engineers and technicians in nuclear safety, coupled with operational rules, must be relied upon to maintain safe handling conditions.

Radiation exposure problems in plutonium handling are discussed. These are becoming more serious as more highly irradiated plutonium must be fabricated. Personnel must be shielded from the Beta, Gamma, and X-ray dosage which is related to some of the isotopes of plutonium and their decay products. With the present material of moderate exposure, adequate protection to allow almost unlimited working time is afforded by lead glass equivalent to ⅛ in. of lead. Lead impregnated neoprene gloves to permit reasonable working times with safe hand exposure are now available. Plutonium of much higher isotopic content (20,000 to 30,000 MWD/T) will probably require remote handling techniques or automatic fabrication processes which result in little or no personnel exposure.

Design concepts for a new fuel fabrication facility are presented. The Plutonium Fuels Pilot Plant has been designed to provide full-scale metal and ceramic fabricating equipment for development of plutonium-containing reactor fuels. This plant will provide experimental reactor loadings for evaluation in the Plutonium Recycle Test Reactor at Hanford. Fabrication equipment for each unit process is housed in individual cells for contamination control, and the building structure is designed as a secondary containment shell to control the free contamination. This facility will incorporate maximum flexibility for the development of plutonium fuels, coupled with improved continuity of operation and personnel safety.

Education

United States Training of Foreign Nationals in Nuclear Science and Engineering by J. D. Perkins, Jr. of the US.

Education and training of required personnel is the paramount goal that must be accomplished in order that development of nuclear science and engineering for peaceful purposes can be attained. Recognizing this, the US Atomic Energy Commission has initiated several training programs to meet specific needs. It is, however, a primary policy of the AEC that nuclear education of the type that can be provided by universities and industries should not be one of its activities. Thus, a strong program has been initiated for the development of nuclear education facilities at universities. However, the most advanced and specialized aspects of training and education cannot be offered by these institutions, and the national laboratory facilities must be called upon for this kind of educational program.

Nuclear educational opportunities of the latter type which are open to both US citizens and foreign nationals can be divided into two categories; 1) formal courses administered and partially financed by the Commission and 2) individual training arranged at our national laboratories.

Among the formal courses is a world famous short course in Radioisotopes Techniques, conducted by the Oak Ridge Institute of Nuclear Studies for the last 10 years. Because of the number of requests from many different countries, the Commission approved in 1954 the admittance of foreign scientists under a quota. This quota is now 30 pct of the total enrollment. The four-week sessions are conducted six times a year. Training is provided in the principal techniques of handling and using radioisotopes in research and in industrial applications. Approximately 300 scientists from 46 foreign countries and about 2500 US scientists have been trained.

A second formal program, the International School of Nuclear Science and Engineering, was established in 1955 at Argonne National Laboratory. Through 1957, approximately 300 foreign participants from 43 foreign countries and 85 US participants have completed this course, which offers a broad background in nuclear science and engineering.

Another expressed interest of the Commission is in the training of personnel related to international and regional agencies, such as the International Atomic Energy Agency, Euratom, OEEC, and OAS.

Maritime applications

The Nuclear-Propelled Icebreaker, by N. S. Khlopkin of the USSR.

A powerful nuclear-propelled icebreaker was launched recently in the USSR. Its nuclear plant guarantees autonomous navigation for a period of more than a year without refueling. This ship will contribute to the promotion of the Arctic region productivity and to the stimulation of economic bonds between the western and eastern part of the USSR's northern territory.

The icebreaker's displacement is 16,000 tons, and the main turbines are rated at 44,000 hp. She is capable of moving through 2-meter-thick ice fields at a speed of 2 knots and can travel in open waters at 18 knots.

The paper contains a description of the reactor and turbo-generating system. The whole plant consists of three pressurized water reactors. Each has an independent primary circuit in which high pressure cooling water is circulating; the heat is transferred to the power circuit through a steam generator. In the second circuit, water of medium pressure is heated and transformed into superheated steam, which is directed to the main turbogenerators, to the auxiliary turbogenerators, and to the auxiliary steam mechanisms and facilities.

There are four main turbo-generators on the icebreaker, producing 11,000 hp each. They supply direct current for electric motors which activate three propeller shafts. In addition, auxiliary turbogenerators on the icebreaker produce alternating current of commercial frequency.

The radiation shielding is erected in the form of iron-and-water layers. Heavy concrete is partially applied in those sections where the application of water tanks is difficult because of complicated geometry. The primary circuit installation area is kept under low pressures by exhauster fans to prevent the spread of radioactive substances into working areas. Air is discharged through a hollow mainmast.

If necessary, as when carrying out maintenance work, radioactive water may be discharged from the circuit into protected tanks. It is dumped into the sea only after cooling and filtering it in ion-exchange filters which reduce its radio-activity to the permissible level.

EUROPEAN COOPERATION BUILDS NUCLEAR RESEARCH LABORATORY

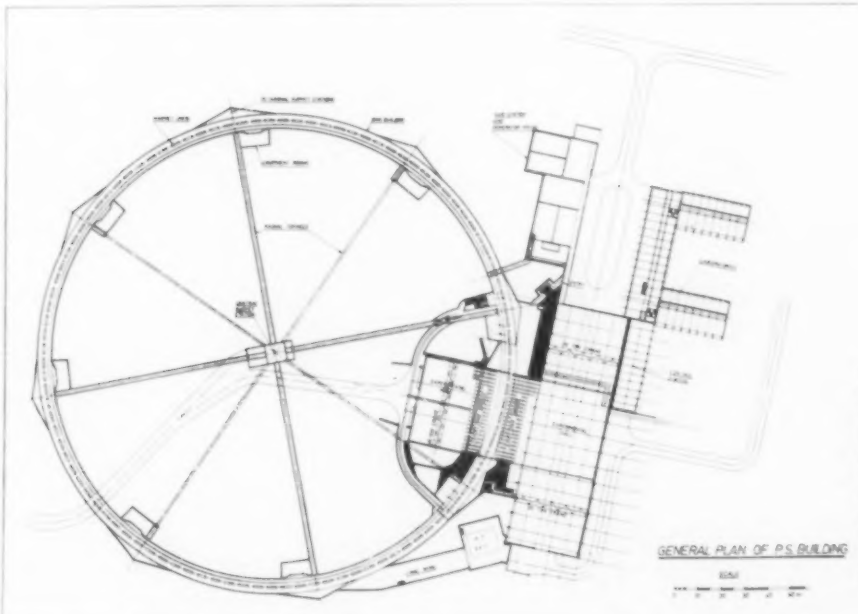
by F. W. Starratt and D. C. Johnston

CERN, the European Organization for Nuclear Research, was born in July, 1953, its 12 member nations desirous of building an international laboratory for basic research in the field of high-enegry particles. With a cyclotron alreday in operation and synchrotron construction advanced to assembly of accelerator components, excellent progress may be reported.

A prime example of the need for expensive and complex *hardware* in pushing back the frontiers of knowledge is found in the field of atomic and nuclear physics. The numerous discoveries made with the cyclotron at Berkeley, Calif., beginning early in 1947, attest to the important part played by the high-energy particle accelerator in such studies.

European scientists, following the progress of American research efforts using the cyclotron, early realized that only by pooling the resources of their various countries could they duplicate such complex and expensive facilities. The prohibitive costs of such installations may be traced to the need for creating high-precision machinery on a large scale, and housing it in an atmosphere which minimizes, if not eliminates, dimensional instability caused by changes in temperature and humidity, shifting and settling of foundations, and other disturbances.

The first formal investigation of the possibility of establishing regional cooperative laboratories was organized following an intergovernmental conference in 1950. As a result of the meeting, sponsored by the United Nations' Educational, Scientific, and Cultural Organization (UNESCO), a board of consultants on this problem was formed. In their report of 1951, two objectives were proposed for European activity: first, establishment of a long range program for construction of an accelerator which would be second to none in the world; and second, immediate construction of a less powerful machine of



General plan of Proton-Synchroton building of the Organization for European Nuclear Research at Meyrin, near Geneva, Switzerland. Still under construction, this synchroton and that being built at Brookhaven National Laboratory will be the two largest.

classical design. The latter objective was established so that European experimentation in the field of high-energy physics might be initiated at an early date.

Meetings on this same subject were sponsored by UNESCO in 1951 and 1952, with all European members of the UN organization invited. In the absence of the Iron Curtain countries, which failed to respond, a preliminary organization was established to formulate long-range plans for a European nuclear research center and the supporting organization. In 1952, Meyrin, near Geneva, Switzerland, was chosen as the site for the laboratory, and in July, 1953, the European Organization for Nuclear Research (CERN) was created by agreement between Belgium, Denmark, France, Germany Federal Republic, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom, and Yugoslavia.

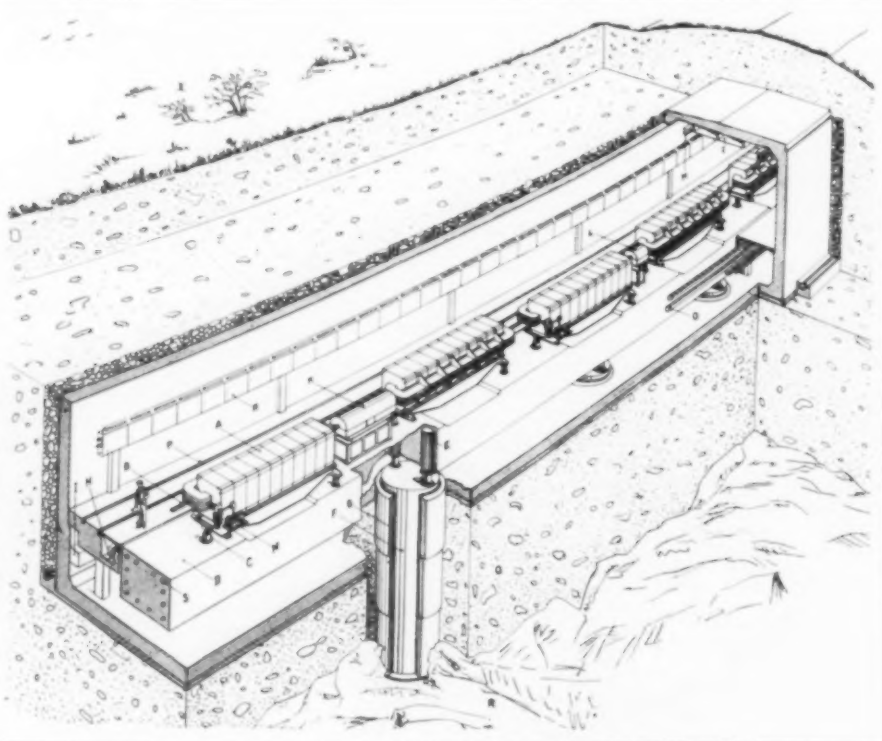
Why a particle accelerator?

Postwar studies of the disintegration of matter by high-energy, charged particles led to the discovery of large numbers of unstable particles. These particles are broadly classified as mesons and hyperons, depending on whether they have a mass between that of the electron and the proton or greater than the proton, respectively. Although many of the particles are individually named, a considerable number are known only as *strange particles*. All are in addition to the neutron, proton, and electron of elementary quantum theory. In order to produce a satisfactory theory of the structure and properties of atomic nuclei—a problem of fundamental importance to our understanding of the nature of matter—more must be known about the extent and properties of such particles.

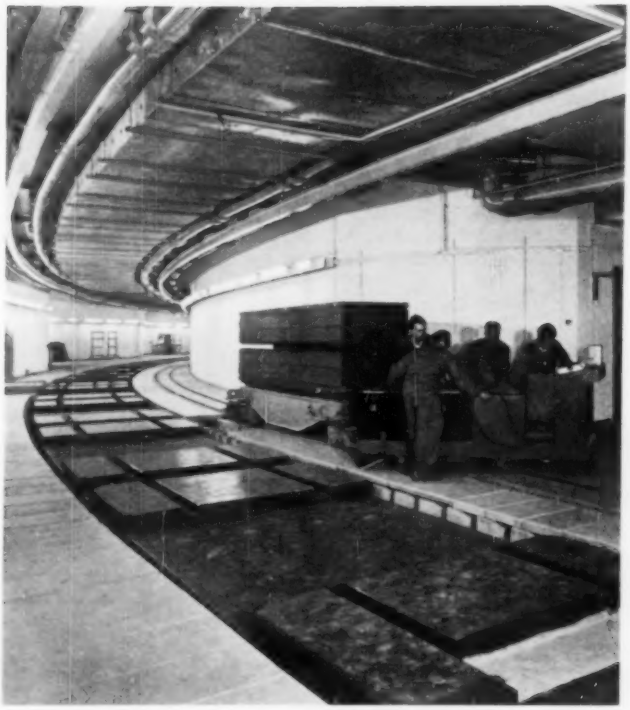
To study these particles, physicists must be able to observe them or the effect of their presence. This, in turn, requires a means of producing such particles for observation. To accomplish this goal, atoms must be bombarded by particles with sufficient energy to break them apart and react with them to create different particles. A natural source of high energy particles exists in cosmic radiation, but such radiation provides particles with a wide range of energies and with unpredictable frequency. In contrast to this, an accelerator can provide particles with known energies when and where they are needed. Accelerators to produce high-energy particles have existed for more than 25 years, but energy requirements have been constantly increasing, requiring the use of new techniques and equipment designs. Thus, in the USSR a 10,000 million electron volt (10 bev) accelerator is already in operation. Two larger units are now under construction elsewhere. These units, which are similar to each other in design and will be the two largest in the world when finished, are at CERN in Geneva and the Brookhaven National Laboratory in the US.

Circular accelerators

Almost from the start of their use, accelerators have been designed to speed particles around a circular or spiral orbit rather than along a straight line. This is because the distance travelled by particles during acceleration makes a linear machine undesirable from the standpoint of sheer size. For example, particles accelerated using the proton synchrotron under construction at Geneva will travel a total distance of almost 180,000 miles in reaching their final energy of 25 bev.



Section of the ring of the CERN synchroton. A, magnet; B vacuum chamber; C, screw jack; D, concrete ring; E, elastic supports; F, concrete column based on rock; G, bitumen; H, 2-ton crane; I, ventilation; K, RF cavity; L, lens; M, vacuum pump; N, electrical cables; O, magnet water cooling; P, rails; Q, earth; R, rock; and S, temperature regulating water pipes.



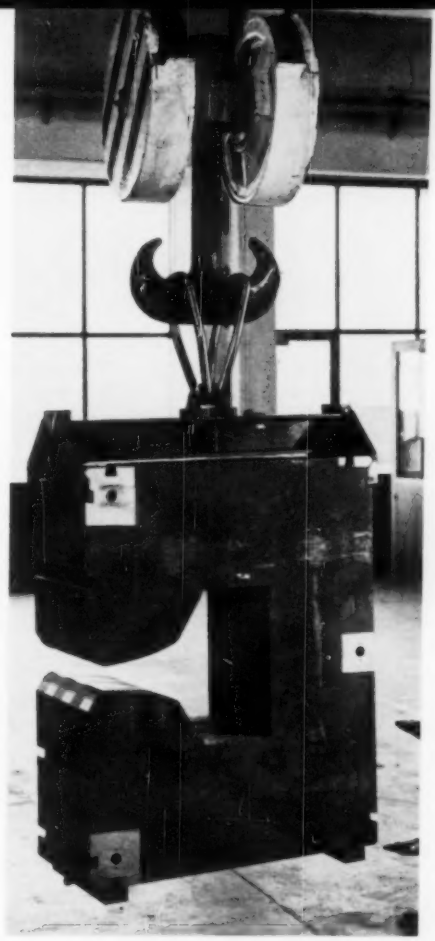


Fig. at right, arrival of magnet block at CERN. Fig, above, assembled magnet being moved into place inside synchrotron ring.

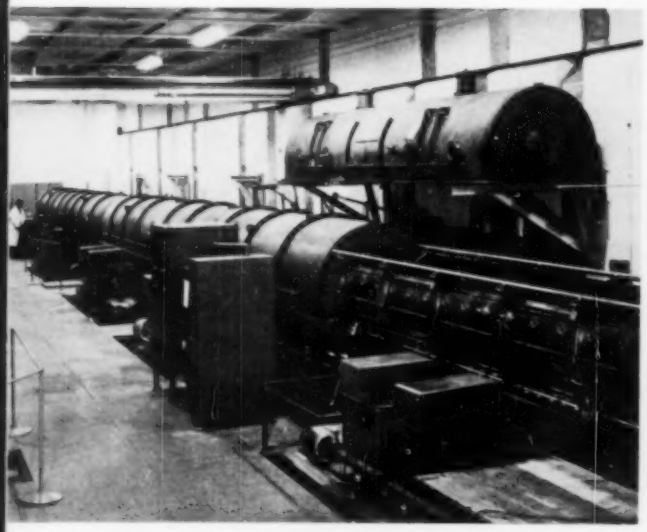


Fig. at right, inside of Faraday cage with horizontal accelerating column and ion source at left and ion source control platform at right. Fig. above, linear accelerator for injecting protons into synchrotron.

Regardless of whether particles move in a spiral path, as they do in the synchro-cyclotron, or in a circular orbit, as in the synchrotron, they are constrained in their path by a magnetic field and accelerated by an electric field. The prefix *synchro* derives from the need for synchronizing the accelerating voltage with the speed of the particles at higher energy levels, and with the decrease in angular velocity due to their relativistic mass increase.

Synchro-cyclotron

The synchro-cyclotron at CERN was put into operation August 1, 1957. It consists of two disc-shaped magnet poles with their faces opposed but not in close proximity. Charged particles are injected into the center of the apparatus where they commence following a spiral path, being accelerated by an electric potential at the same point during each revolution. Finally, they are ejected at high energy levels along the circumference of the space between the magnets. Energy levels for particles accelerated in such a unit are limited by the strength of the magnets, which in turn depends on their size. This imposes economic limitations on the use of such machines to accelerate particles above about 1000 mev.

It is for higher energy levels that the synchrotron is used. Particles accelerated in this machine speed faster and faster around a circular path of large diameter. The magnets in this machine are disposed circumferentially about the tube which encloses the circular path of the particles. The design of this machine is more economical in the use of magnets, giving more than forty times the energy level of the synchro-cyclotron for a one-third increase in magnet weight.

The CERN synchroton

It is this accelerator which is the pride of European nuclear physicists. Still under construction at an estimated cost of $25 million, this machine's circular tube already rests beneath the surface of the ground on its site near Geneva. A significant mark in the progress of construction was passed earlier this year when actual assembly of the accelerator components began. Operation of this unit is expected to begin in 1960.

Particles will make almost half a million revolutions of the 200-m diam tube, gaining 50,000 electron volts of energy each time around to reach the final level of 25,000 million electron volts. Discharged at a speed nearing that of light, they will be used to bombard the nuclei of matter placed in their path.

The stainless steel vacuum chamber through which the particles will travel has an elliptical cross section 8x15 cm and a wall thickness of 2 mm. Fifty vacuum stations about the circumference of the tube lead to 10-cm diam diffusion pumps.

Some appreciation of the control problem involved in such an installation can be gained from the realization that in their half million revolutions round the tube, the particles must never come in contact with the chamber walls. It is this control problem which leads to the necessity for extremely high dimensional stability.

Structural design problems

Construction of the 200 m diam ring on which the magnets and vacuum chamber rest was probably the most difficult problem. Stability within the limit of one part in 100,000 was achieved by resting the continuous concrete ring guides on 80 concrete pillars, 2 m in diam, imbedded in solid rock. In order that changes in temperature might have a uniform effect on all of the supports, it was necessary to take special precautions to insure the uniform properties of the concrete used in their manufacture.

Finally, it is absolutely essential that the temperature of the ring remain constant, since a variation of 10°C in the temperature would produce a variation of more than 1 mm in the diameter of the ring. The building which houses it, therefore, will have its temperature controlled within 2°C.

One hundred magnet units-250,000 laminations

The magnets which keep the particles in their circular path consist of 100 units weighing a total of 3200 metric tons. Each of these units in turn contains 10 magnet blocks, which are laminated from 250 sheets of 1-m cold-rolled transformer sheet. The laminations are precision stamped, interleaved with paper, and bonded with a hot-setting resin. Supplier of the magnet steel is the Ansaldo Shipyard in Genova, Italy.

Although handling the laminations and fabricating the magnet blocks from them may seem to be a formidable manufacturing problem, their very number holds the solution to the basic problem in the design of the machine. The fluctuations of magnetic properties between different lots of normal grades of transformer steel are too great to be tolerated in an accelerator. Thus, it is necessary to insure that all the magnets in the accelerator are as nearly alike magnetically as possible. Among the laminations themselves, it is necessary to eliminate any repetition of systematic properties, such as variations which might occur between the sheets at the top and bottom of an annealing furnace, as well as the effects of uneven aging. A statistical solution to these problems was determined, taking advantage of the large number of individual laminations, which makes it possible to obtain uniformity by mixing the laminations as they are fed to the fabricating operations.

Injection and bombardment

Generated in a Cockroft-Walton cascade generator, the particles will pass into a three-section Alverez-type linear accelerator to reach an energy level of 50 mev. The stream of protons, thus produced, will be fired into the proton-synchrotron. When they have reached the desired energy level, the particles will emerge through a 30-cm slit into one of two experimental halls adjacent to the ring. In these halls, which are shielded by several hundred concrete blocks each weighing almost 2.5 metric tons, the streams of high-energy protons will be used in nuclear experiments.

These experiments will fall roughly into two types: first, by bombarding matter with the particles, hyperons and mesons will be produced, permitting nuclear scientists to study them and possibly to make discoveries of new particles; second, the machine will allow its users to pioneer in the study of nuclear reactions at energies higher than those available with the new Soviet machine, a 10 bev accelerator.

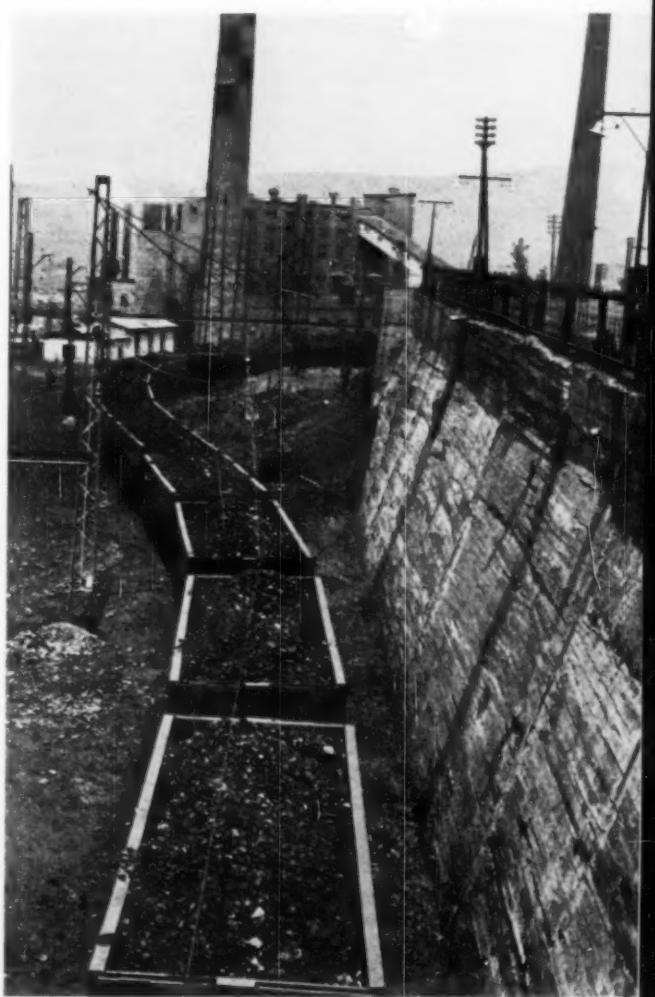
This exciting experimental work, combining the efforts of 12 western European nations, will begin with the completion of the CERN proton synchrotron in 1960.

SOVIET BLAST FURNACE PRACTICE

Continuing the JOURNAL OF METALS' *survey of operating practice in major Soviet steel mills, we present a survey made by a leading American authority on blast furnace practice during his recent visit to the USSR as a member of a group sponsored by the American Iron & Steel Institute.*

by J. H. Strassburger

Ore train at Magnitogorsk



The recent visit of a team of American steel experts to the USSR permitted detailed examination of a number of major steel plants, including Chelyabinsk, Magnitogorsk, Kuznetsk, Zaporozhstal, Dneprospetstal, and Krivoi Rog. However, previous American teams had visited some of these plants and reported on them . . . JOURNAL OF METALS, March 1958 . . . therefore, I shall limit my description of blast furnace and sintering operations to two plants: the Kuznetsk Works at Stalinsk in south central Siberia and the Zaporozhstal plant in the Ukraine.

Kuznetsk

Kuznetsk is an integrated steel plant located in the center of what is reported to be the third largest coal deposit in the world, outranked only by the Eastern Siberian area No. 1 and the US Appalachian area No. 2. Coal reserves amount to an estimated 450 billion tons.

Iron ore deposits have been found in the area at Kakasia and at other nearby locations. Most of the ores are magnetic. This region also has dolomite, sand, and clay deposits.

Plant construction was started in 1930 with the first blast furnace blown-in in 1932. Nine months later the open-hearth department and rolling mills were started for the production of rails, beams, and heavy shapes.

Sinter is made at the ore mines about 60 miles away and, although self-fluxing, contains a large amount of fines, stated to be 30 pct -$\frac{3}{8}$ in. This has an adverse effect on good blast furnace operation. In addition to the fines created by handling of the sinter six times between the sintering plant and the top of the blast furnaces, the sinter contains an appreciable amount of unburned fines. The iron content of the sinter is about 52 pct with 11 to 13 pct

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SiO_2, whereas, the ore contains 49 pct Fe and has a basicity of ($CaO:SiO_2$) 0.4 as compared to 1.35 to 1.40 pct for the sinter.

Coke ovens

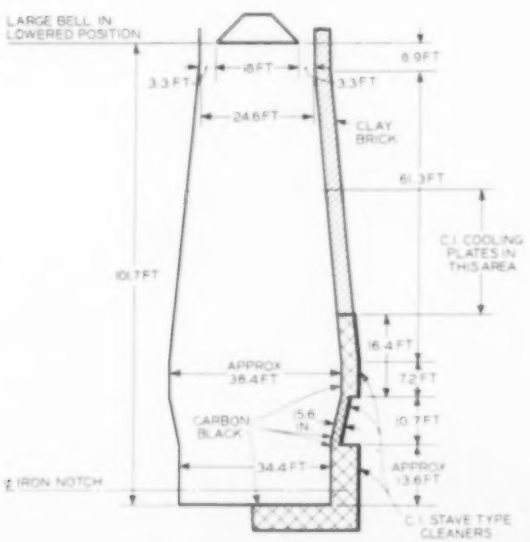
There are six batteries of coke ovens at Kuznetsk, each containing 55 ovens, or a total of 330. The ovens are 16 in. wide and 14 ft high. The plant is pushing 15½ hr coke producing about 6000 net tons daily. The coke analyses show 8.5 to 8.6 pct ash, 0.5 to 0.6 pct S, 6 to 7 pct moisture, and 22.5 to 23 pct volatile matter. Coke is 10 to 11 pct moisture, 0.5 pct S, and 2.5 pct moisture.

Blast furnaces

At this plant there are four furnaces of 46,000 cu ft working volume, with a hearth diam of 26.6 ft. This plant has a completely automatic scale car and skip operation, which includes the handling of all ore, limestone, and coke.

Blast furnaces produce about 1700 net tons of iron daily at a 1500 lb coke rate, 1200 lb slag volume, 300 lb stone rate, and 140 lb of dust. They cast six times daily into 70 ton ladles. From 85,000 to 87,000 cfm of wind are blown, with blast temperature averaging 1500°F or a maximum of 1600°F. Moisture is added to the blast ahead of the stoves and ranges about 11 grains per cu ft. Top temperatures are from 570° to 650°F with 9 to 10 psig top pressure. These furnaces also have sixteen 7-in. tuyeres which burn out at the rate of about 3 per year. Sinter amounts to 70 to 80 pct of the burden with the balance made up of ore which ranges in size from 1½ in. to 2 in. with 10 pct -½ in. Forty pounds of scrap are charged per ton of iron produced.

Furnace hanging exists due to the sinter fines, but lost time amounts to only 0.3 pct per year. It is significant that in all of the furnaces visited, the blast is maintained on a continuous basis with practically no checks during the casting of the furnace.



Above, Soviet blast furnace design expected to be in operation in 1960 with a production of 5000 net tons per day. Volume to be 77,660 cu ft with 24 tuyeres blowing 176,500 cu ft per min at 42.7 psi, and top pressure of 21.3 psi. At right, view of Magnitogorsk taken by John Chipman.

It was stated at one of the plants, that a check tends to upset the entire furnace operation because the stock settles down, and the fluidized condition of the blast furnace is altered, causing an upset furnace condition.

Lining life at Kuznetsk averages 3½ to 4 years on the first lining above the mantle, with the second lining lasting about five years. The complete lining, including the hearth, lasts 9 to 10 years with 7,100,000 net tons of iron per lining. Furnaces No. 1 and No. 3 have carbon hearths; No. 1 furnace has both carbon walls and bottom, while No. 3 has only carbon walls.

In regard to the bell operation, it was stated that three to four years were obtained on a large bell. One of the requirements for a good bell operation is a rigid, stiff, bell with sufficient elasticity in the hopper to prevent warpage. In addition, the surface of contact is covered with weld metal which is ground and polished.

Stoves: There are four stoves per blast furnace with automatic stove changing on three furnaces and one soon to be installed on the fourth furnace. Stoves are on blast 1½ hr, and ample time is provided for stove heating. About 24 pct of the total gas is burned in the stoves with burners having a capacity of 29,500 cfm per stove. At Kuznetsk, the stove cycle is as follows: one stove on blast, two stoves heating, and one stove soaking. In addition to the automatic control, there is also a manual board for the control of the stoves.

Automatic charging

At the skip pit, there is a hopper of a fairly large size, which can hold the charge from the scale car. The hopper feeds the skip on an automatic filling cycle. The scale car itself is automatic and operates without a man. The car has five different programs which can be altered or adjusted by a punchboard type of control. The program at the time of our visit consisted of five steps as follows: first, 900 lb of limestone was charged from the bins to the car, followed by 14,500 lb of sinter. In the third step, 15,400 lb of sinter was charged, and at the fourth step 2200 lb of furnace scrap and turning were used; the fifth step was identical to the fourth.

Gas sampling

Another practice at this plant is to take gas samples just below the stockline at right angles to the shell. Two samples are taken on opposite diameters at the same time. It requires about 30 min to take the set of four samples once every 24 hr. Ordinary heavy 1½ in. pipe without cooling is used for sampling. Two men are required for this, although automation is being considered. The Soviets claim that this method of sampling can tell them whether the furnace is running smoothly or channeling. If a channel condition exists, they have found it can continue for many hours, and that the gas-analysis probing at the top of the furnace can give them a good picture of the internal working of the furnace.

Furnace with hearth cooling

Kuznetsk has hearth cooling on one furnace which was installed in 1956. Hearth cooling is accomplished by circulating air in the foundation under the brick hearth. The air is furnished by two fans at 10,000 cfm with a 40 HP motor at 3 in. air pressure. Each fan has two square ducts with two sets of nine pipes from each square duct or a total of four groups of pipes. The center ducts, of which there are two, have nine 8-in. pipes each, with two outside ducts having nine 5-in. pipes each or a total of 36 cooling pipes in the foundation. The air rises about 12° to 14°F in going through the foundation. It is claimed that this method of cooling will maintain the bottom for a much longer period and prevent cracking. In fact, the objective is to obtain an indefinite life at the bottom.

Kuznetsk improvement program

With reference to improvements, we were given the following program:

1) Increasing the iron content of the burden so that the sinter on dry basis will contain a minimum of 60 pct Fe, with SiO_2 reduced to 6 to 8 pct;

2) The second step would be to lower the coke rate further by the use of higher blast temperatures and optimum moisture content;

3) The use of oxygen enrichment; and

4) Complete automation of the furnace operation by a pressure differential control in the stack with the pressure take off at three different points. This would control wind volume, temperature of blast, and probably moisture.

Zaporozhastal

The Zaporozhstal plant is also completely integrated, except for the coke ovens which are adjacent and operated as a separate company. It was started in 1933 and was completely ruined during World War II. All the equipment was removed by the Russians, but the buildings and other parts of the plant were demolished. The plant was put into operation again in 1947.

It has the following departments: A sinter plant with six strands of 540 sq ft each, producing a total of 14,300 tons of sinter per day or 4,750,000 net tons per year. The sinter contains 46.5 pct Fe, 14.5 pct SiO_2, and 1.3 pct MnO, and has a basicity of approximately 1. There are five blast furnaces with the smallest producing 1300 and the largest 2000 tons per day for a total production of 2,750,000 net tons yearly. Four furnaces produce basic pig iron, and one foundry iron. Sixty percent of the pig iron produced is sent to the open hearth furnaces, and the balance of 40 pct is sent to other plants.

Blast furnace department

The blast furnace department consists of two 34,000-cu-ft furnaces, designated as No. 1 and No. 2. No. 3 has a working volume of 46,000 cu ft, No. 4 has 43,800 cu ft, and No. 5 has 49,000 cu ft. The latter has a hearth diam of 26 ft 10 in. and produces over 2000 net tons of iron daily at a 1580 lb coke rate. Limestone amounts to 500 lb per ton, with a slag volume of 1740 lb. Dry dust ranges from 120 to 140 lb per ton. This furnace is normally operated on 85 to 90 pct sinter, which is charged at a temperature of 1100°F.

A wind volume of 88,000 cfm is blown with moisture added in amounts from 10 to 11 grains per normal cu ft. The average blast temperature is 1570°F with a maximum of 1650°F. Top temperature is 750°F, and top pressure amounts to 11.5 psig. Each furnace has sixteen 7-in. tuyeres and operates with three stoves of 270,000 sq ft each. Tuyere changes amount to about five per month.

Low grade raw materials: This plant is handicapped by relatively low grade raw materials with the ore containing 51 to 52 pct Fe and 19 to 20 pct SiO_2. The sinter contains only 46.5 pct Fe and 14.8 pct SiO_2 because of the lime added to make a basicity of 1. Coke contains almost 10 pct ash with 1.8 pct S; so, a large sulfur load must be handled. Nevertheless, furnace operation is relatively good, due largely to the use of large amounts of sinter, high top pressure, and high blast temperature . . . all typical of the Soviet furnaces. Lost time was stated to amount to only 0.4 to 0.5 pct.

Lining life: Hanging occurs about twice each month per furnace. Lining life is relatively good with five years minimum on the stack lining. It was stated that the No. 1 stack lining above the mantle usually produces 3,600,000 net tons of iron, and that No. 2 stack produces 4,400,000 tons with the hearth lasting for 10 years or two stack linings. Only in No. 3 furnace is carbon used in both the hearth and side walls of the crucible.

Future plans: The Zaporozhstal plant expects to rebuild its stoves for 1800°F blast temperature. They are also planning to use natural gas injection through the tuyeres, stating that they hope to get a saving of 5 pct in coke and no increase in iron. Quantities of natural gas from 2100 to 2500 cu ft per ton of iron will be used; the gas will not be preheated. This practice is evidently an attempt to substitute gaseous fuel for expensive high-sulfur coke.

At this plant the maintenance of wind volume at all times without checks was strongly stressed as an important factor in furnace production.

Conclusions

All of the plants visited had been constructed since 1932 and were, therefore, relatively modern in their fundamental aspects. Much has been done in recent years to reduce the coke rate; most furnaces operate with high top pressures, and relatively high-temperature, humidified blasts.

They have been operating on high sinter burdens for some time, but at one plant the sinter produced at the mine contained some 30 pct fines by the time it had reached the furnace top. A second plant is having difficult operating problems with high-sulfur coke and relatively low iron burden.

Future trends appear to be toward increasing the iron content of the burden, higher blast temperatures, and automation of furnace operation.

OPEN-HEARTH SHOPS OF THE USSR

Close observation of Soviet open-hearth practice showed that many factors have contributed toward their high output rate. But, particularly significant are the hot-metal spout and suspended basic furnace roofs.

by K. C. McCutcheon

AMERICAN steel experts, who recently visited the Soviet Union under the auspices of the American Iron & Steel Institute, were conducted through some of the best Soviet mills. The oldest was built sometime after 1933. They followed Western designs of that time, but they have been improved according to the most recent ideas.

We visited **Chelyabinsk,** South Urals District in Siberia—capacity 1,892,000 tons of ingots per year from 11 open-hearth furnaces capable of producing 1,642,000 tons, and five electric furnaces of 242,000 ton capacity;

Magnitogorsk, South Urals District in Siberia—capacity 6,600,000 tons of ingots per year from 28 open-hearth furnaces;

The **Kuznetz** combine at Stalinsk, South Central Siberia—capacity 3,300,000 tons of ingots from 13 open-hearth furnaces and two electric-arc furnaces;

Dneprospetstal in the Ukraine—1,050,000 tons of ingot capacity per year from 16 electric furnaces;

Zaporozhstal in the Ukraine—2,920,000 tons of ingot capacity per year from 12 open-hearth furnaces.

Some of the group visited Krivoi Rog, which was destroyed during World War II and is now being rebuilt. It is expected to produce 900,000 tons of ingots this year by the LD process. Six open-hearth furnaces are being built.

High output rates

Open-hearth furnaces in these plants are charged with scrap, 60 to 70 pct hot metal, and ore. They are fired with mixed gases. But we found them producing at as high a rate as some of the best American furnaces and better than many, which would not be expected with mixed-gas firing.

This they do not accomplish by any one thing, but by a combination of a number of things. They have good technical and engineering understanding of problems. Their technical and operating force has good practical knowledge and ingenuity, and their morale is high. They have set their goals and, all know them. Incentive pay is earned when they reach them. In addition to pay, public recognition is given to individuals and crews. The union, in addition to bargaining for incentive pay, vacations, and fringe benefits of all kinds, has an important committee which works on increasing production. Furthermore, steel workers are furnished with technical instruction and are encouraged to take these classes in order to increase their technical knowledge and thus merit promotion to better jobs.

Good plant layouts

The way these plants are laid out and equipped would make any open-hearth man's heart swell.

The smallest charging pans seen were 32 cu ft, and they have 42 and 61-cu-ft pans, which seemed to be well loaded and leveled. There are low-type charging machines, one for each two or three furnaces. In one plant, we saw them charging one furnace with two machines.

To get the hot metal poured at the right time we saw an ingenious innovation—hot-metal spouts with a water-cooled nose. Equipped with slings, they are suspended in the end doors when about ready for metal, and are up high enough so that loaded pans on buggies can pass underneath to other furnaces. Two to four ladles of metal would be received by the furnaces, and the spouts would remain in position until the charge was completed. Two ladles of metal are sent down from the mixers on transfer ladle cars and poured, one at a time.

Besides the usual front flush into a pot on a transfer buggy underneath, there is a flush hole at each end in the back wall. Thus, they are prepared for a good, rapid flush, which they should get, if metal is poured at the right time.

At Magnitogorsk, they have 1200-ton mixers in every shop except No. 1, which is the new shop, and which still takes metal directly into three 250-ton

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furnaces. At the No. 2 shop of Chelyabinsk, there is a 550-ton mixer in the pit aisle for one 198-ton and five 105-ton furnaces. We were told that the hot-metal spout stays permanently in the back. At Kuznetz, each shop has a 1200 to 1400-ton mixer, while at Zaporozhstal there are two 1430-ton mixers. Metal is transported from the blast furnaces to the mixers in the same Kling-type 80-ton ladle, which is used for transferring metal to the open hearths.

All shops, except No. 2 at Chelyabinsk, are equipped with hot-metal cranes at the rate of one for each three furnaces, or better.

Pit-side arrangements

The No. 2 shop of Chelyabinsk is for special steels; it is equipped with five 100-ton furnaces tapping into one ladle, and one 198-ton ladle tapping into two ladles through a bifurcated spout. It has five 154-ton ladle cranes, one of which serves the mixer located in this aisle. This shop, which is the oldest shop, is unique for the ones that we visited; it is equipped with four 515-ton overhead rotating cranes which pick up charging boxes set up at floor level by slings in groups of four.

On the pit side, all shops are more generously equipped with pouring cranes than in the US. In order to judge their supply of cranes, it is well to realize that they are going to many two-ladle heats, which means a 50 pct increase in slag pots to be handled per furnace and a 100 pct increase in steel ladles. For instance, at the Magnitogorsk No. 2 shop, with one 220-ton furnace pouring into one ladle and twelve 440-ton furnaces pouring into two ladles, all with two stoppers, this means 25 steel ladles, 36 slag pots, 50 nozzles, and 5 stopper rods. This is compared with a similar size shop using single-ladle pouring where 13 ladles are required, 13 nozzles, 13 stopper rods, and 26 slag pots.

From a production standpoint, the Soviets may be able to justify the higher proportion of cranes which they use. In the US, we tend to be short of auxiliary equipment in the form of charging pans, switching service, charging cranes, hot-metal cranes, and ladle cranes. It might be a good idea to restudy this, since all of these services enter into the high production rates which we observed in the USSR.

In addition to the matters just mentioned, part of the process of tapping heats out in fast time is attained by releasing heat in the hearth at a high rate and having furnaces which will stand up in such a practice.

Mixed-gas firing

From what was seen, it appears that the Soviet steelmakers have a good scientific knowledge of fuel burning and have developed a practical way of using mixed gases. In all open-hearths which we saw, they were using blast-furnace and coke-oven gas, both preheated in a regenerator chamber.

This mixed fuel was introduced through a Blair port. Its velocity and momentum is increased by using a compressed-air injector to blow external air through a 6-in. line into the port through the end bulkhead. During the melt down, 25 pct of the total fuel is introduced in the form of tar or pitch, atomized with steam. Later, when fuel is reduced, the coke-oven gas is decreased, usually with no change in the others. All flows are controlled by instruments, and reversals are made automatically, based on time, with a protective high-temperature limit. Where they have oxygen available, it is introduced into the furnace through pipes on either side of the Blair port, parallel to the port slope. Fuel consumption is reported as 3,900,000 Btu gross, including auxiliaries.

Suspended basic roofs

Another thing of note in Soviet practice is the sprung or arched suspended basic roof with optional hold-down which is used in every furnace we saw, and is reported to be universally used.

The roof life reported at Magnitogorsk is 420 to 450 heats on the 440-ton furnaces and 650 to 700 heats on the 220-ton and 275-ton furnaces, usually without patching. On the 440-ton furnaces, they take out slag at mid campaign, replace the ten top courses of checkers and renew end walls, port bridgewalls, front walls, and top of backwalls. This requires 48 hr. For the smaller furnaces, this is done twice. Other plants are very close to this. This gives an over-all availabilty of 94 pct or better, it is said.

One thing which contributes to these results is, without doubt, their practice of keeping the furnaces hot between heats and also during the front wall and end replacement period, when they say that they use auxiliary gas burners in the doors. We saw one furnace down for slag removal in No. 1 shop at Magnitogorsk when the burners were not in use.

Roof brick: The analysis given for the roof brick was 69 to 71 pct MgO, 10 to 12 pct Cr_2O_3, and 9 to 11 pct Fe_2O_3. At some plants the same brick is used in fronts and backs. In the port ends, the analysis given was 51 to 56 pct MgO, 16 to 19 pct Cr_2O_3, and

Open-hearth furnaces at Magnitogorsk; photograph by John Chipman.

12 to 15 pct Fe_2O_3. In addition, they reported improving the life by changing the grain and increasing pressure in the brick presses, and burning hard. They appear to have succeeded by these means in getting a brick which does not absorb much FeO in the melting zone of the furnace and does not swell and grow.

Roof construction technique probably helps in much the same way. In the transverse direction of each ring, every ninth pair of bricks is supported by a ½x2 in. pin, extending through a ⅛-in. plate into each brick. The plate extends up and is bent over a pair of back-to-back angles, which extend from one end of the roof to the other. These occur about every 2 ft of transverse arch. At each set of buckstays, an arched structural member spans from front to back, about 30 in. about the roof. The longitudinal backed angles are suspended to these cross-structural arches. Between each pair of bricks is a 1/16 in. plate with a hole through which the ½x2-in. pins extend into shallow holes into each side of every roof brick, thus loosely suspending each brick in the ring by the two adjoining bricks. This tends to allow the brick to be open on their inner hot ends.

The straps, which support the longitudinal angles have around them a sleeve of pipe, which can be used as a hold-down. When the rings are put in, they are supported by centers, as is usually done in putting in arches. When the centers are removed, the roof is expected to drop about 2.4 in. If it does not do so, results are not as successful, it is said. This sinking of the roof and the loose suspenion between the supports, due to play in the pin sockets, probably prevents spalling of the ends caused by pressure, resulting from temperature and some growth in the brick.

In order to understand more fully just how the roof was constructed, some of us climbed up a ladder on the end of a furnace, which had about 180 heats and spent some time examining it. This was at Kuznetz. None of the hold-downs were operating as hold-downs, and they said that this was often the case throughout the run. We saw photos of the furnaces at Zaporozhstal on which the main suspension structure was somewhat different, and the suspending straps were not equipped with hold-down pipes.

The roof construction, and the brick analysis, and physical structure probably all contribute to the good results attained. The Soviets said that they are not satisfied and are trying to improve so as to get 1000 heats per roof.

A few interesting details

The following are a few details of interest to open-hearth men.

On the Soviet furnaces, the front bucks slope out at about 11° to facilitate a weekly patching with basic paste.

At Kuznetz, it was reported that skew back coolers (and probably Blair-port coolers) were cooled with steam vapor, which was returned to the boilers.

The jambs of the doors are also cooled about half way up with pipe coils.

Tap holes are closed from the front by means of a charging pan, which has a pipe welded to the bottom at the outer end. Refractory filling, usually magnesite, runs into the hole through the pipe.

The nozzles are made of magnesite and the stopper heads of clay brick.

Bauxite is used in place of fluorspar.

The doors are banked by means of a large box filled with dolomite and equipped with two chutes, carried by an overhead crane. With this, they can bank all doors more quickly, probably, than with a Payloader.

At the Zaporozhstal plant, there are two oxygen jets in the roof of each furnace which are used for 15 to 20 min on the incoming end only at the rate of 3600 cu ft per hr. The injector is a 4-in. steel pipe for water jacket with a copper nozzle end of the same outside diameter with a straight center hole and four 45° orifices, equally spaced.

Conclusions

As is evident from this discussion, many things have contributed to the good results obtained by the Soviets on their open hearths, but I feel that the hot-metal spout and the basic roof set-up are unique and, probably very important. From what I have mentioned, it is evident that the Soviet metallurgists have made great progress in refractories, fuels, and instruments.

Table I. Soviet Open Hearth Furnace Tabulation

	Stalinsk			Chelyabinsk			Magnitogorsk				Zaporozhstal	
OH Production 1957 (NT)	3,300,000			1,650,000			6,600,000				3,025,000	
No. Furnaces	4	11		5	3		3	4	3	21	10	2
Capacity, tons	210	420		105	198		396	220	275	440	220	440
Furnace Dimensions												
Hearth Length, ft	48.5	(8) 48.5	(3) 52.5	32.8	(1) 41.0	(2) 46.0	46.0	44.5	47.5	47.5	50.0	50.0
Hearth Width, ft	15.8	17.1	17.1	13.1	13.1	16.4	16.4	15.8	16.7	16.7	16.8	17.6
Hearth Area, sq ft	765.0	830.0	900.0	430.0	538.0	755.0	755.0	700.0	800.0	800.0	840.0	880.0
Depth of Bath, in.	31.0	48.0	—	31.5	38.0	35.0	47.0	33.5	35.5	49.0	37.5	48.0
Charge												
Hot metal		63 pct			65 pct				66 pct		65 pct	50 pct
Scrap		37 pct			35 pct				34 pct		36 pct	50 pct
Ore		6 pct			6 to 10 pct				6 to 10 pct		8 pct	5 pct
Limestone		5 pct			—				4 to 4.7 pct		4 pct	3 pct
Productivity, NT per hr	20.5	29 to 31		12.2	20		26	24.2	30.8	33	28	41
Fuel consumption per ton steel	3,900,000 gross Btu			4,360,000 gross Btu (includes drying)			3,900,000 Btu (includes drying)					
Compressed air used, cu ft per hr (Through gas port)	70,000			16,000			24,700				—	
Roof life in heats	600 to 700	400 to 500		600	480 to 520		380 to 400	650 to 700	650 to 700	420 to 450	520	440
Tapping	1 ladle	2 ladles double stopper		1 ladle	1 ladle		2 ladles double stopper	1 ladle	2 ladles double stopper		1 ladle	2 ladles double stopper

A review of Soviet and Western literature covering the following four aspects of this field: theories of strengthening, the relation of strength to bond forces and diffusion, theories of high-temperature strength, and the relation of high-temperature strength to phase diagrams.

Drawing by David Cain

RECENT SOVIET LITERATURE on STRENGTH - TEMPERATURE RELATION

by R. W. Guard, W. R. Hibbard, Jr., and R. E. Hoffman

Within the last three to five years a considerable body of Soviet papers have been published on theories of strength and elevated temperature properties. The present paper compares the status of Soviet work on the subject as evaluated by comparison of these papers with the unclassified literature of the Western companies in a comparable period. It represents a critical evaluation of that part of Soviet metallurgy dealing with elevated temperature behavior of materials, and is valid to the extent which their literature represents the actual state of knowledge in USSR.

In general, the reviewed material was presented by research laboratories of the Academy of Sciences and a few central industry laboratories. Production and development work on actual materials is not covered. The most active single group in this field is that at the AA Baikov Metallurgical Laboratory of the Academy which includes Kornilov, Savitskiy, Oding, and Ivanova.

R. W. GUARD, W. R. HIBBARD, JR., and R. E. HOFFMAN are with the General Electric Co., Research Laboratory, Schenectady, N. Y.

The review covers four different aspects of this field: theories of strengthening; the relation of strength to bond forces and diffusion; theories of high temperature strength; and relation of high temperature strength to phase diagrams. In discussing each of these topics the Soviet emphasis on phenomenology rather than mechanism should be noted. The major part of the work reviewed has been published in the last few years and is given in the bibliography attached.

Theories of strengthening

The significant factors related to strength have been summarized as follows (Zakharov,[28] Bochvar,[24] Kishkin[29]):

A) An inherent technical strength derived from elastic behavior and related to interatomic binding. This strength may be evaluated by:
   1. Heats of sublimation,
   2. Atomic specific heat,
   3. Melting temperature,
   4. Interatomic spacing,
   5. Energy of self-diffusion, and
   6. X-ray spectra measurements

B) Structure sensitive strength derived from:
   1. Crystal lattice structure and dimensions,
   2. Structure within grains (blocks, subgrains),
   3. Polycrystalline grain structure (size, shape and orientation of grains),
   4. Structure of grain boundary, and
   5. Structure and distribution of second phases

The basic means of increasing strength include:

A) Mechanical deformation, i.e. fragmentation of the lattice and blocking of shear by the lattice fragments.

B) Solid solution hardening, which is related to the chemical and electronic effects of solute atoms on bond strength.

C) Dispersion hardening, which primarily causes blocking of shear.

D) Strong second phases segregated along grain boundaries, resulting in complex structures containing low diffusing atoms which increase the structural stability.

There are two different factors emphasized in discussing alloying effects. In one case the effects are related to bond strength of the matrix; in the second case the strengthening is related to the phase diagram. For example, solid solution hardening is related to the polarizability and deformation of electron shells (Shishokin[44]). Strong bonds are created by solute atoms with excess charges forming blocks or clusters (Borovsky[45]). Optimum alloying capacity of a solute element is related to maximum solubility. Large alloying capacity is associated with large temperature dependence of plasticity (Presnyakov[7]). Solute atoms increase interatomic linking, pulverize the grains, distort the lattice, raise the recrystallization temperature, and slow diffusion.

Heat resisting strength characteristics are related to modulus at temperature, which is interpreted as a measure of binding and inherent technical strength, (Dzagurova, Zakharov and Sirota[46]) and to recrystallization temperature. Creep is primarily controlled by the high temperature strength of second phases and their distribution. (Glasov, Zakharov and Stepanova[13]).

Much of the work is descriptive and without mechanistic explanation, e.g. highest hardness in binary nickel alloys results from additions of 19 pct Cr, 12 pct Mo, 11 pct W, 4 pct Ti, or 1 pct Al (Blanter, Kuznetsov, Lozinskii and Sinodova[48]). Dislocations and defects are only occasionally mentioned (Bochvar[34]). The phenomenology is primarily intuitive and is not uniquely supported by data.

Alloying principles are empirical, e.g. make the most complicated binary alloy possible, add the most complexing third element and then add the most complex fourth, etc.--------etc., additions should be made as compounds rather than as elements because compounds are twice as effective. (Zakharov[49]).

Most of the strength concepts are geometrical or are related to the periodic table type characteristics of the constituents and microstructure on an empirical basis. Much of the Soviet approach was used in the US five to ten years ago. Many of the above statements regarding strength will be found in US summaries such as Schwope (Trans. ASM, 46A, 1954, p. 108) or Nisbet and Hibbard (Trans., AIME, 197, 1953, p. 1149). While US authors were inclined to speculate on a minimum of data, Soviet authors are collecting large amounts of supporting experimental information. In recent years US workers have become more mechanistic and less phenomenological, as evidenced by Parker and Washburn (Trans. ASM, 49*A*, 1957, p. 227). This latter paper was written about the same time as most of the Soviet papers reviewed here. An interesting contrast is the 1957 ASM volume on Creep as compared to the 1957 Soviet volume on Research on Heat Resistant Alloys. The state of empirical knowledge appears to be similar in both countries, (the Soviets may have more supporting data). The US and the Western world have taken a step well ahead in mechanistic studies in the past four to five years, while the Soviets are just beginning to investigate mechanisms, defects, and dislocation.

Relation of strength to bond forces

A very large effort is going into the correlation of bond strength (measured by X-ray techniques) and the mechanical strength of metals. This work is the result of the school of Kurdiumov. While the measurements of interatomic forces are on reasonably firm grounds, the correlation of this force and strength is made on the generally unwarranted assumption that the strength is not determined by the microstructure, (i.e. distribution of solutes) and has no basis in the theory of dislocations. Although a change in average bond strength does occur, it may well be that the local lattice distortions are much more important. No quantitative calculations can be made on the basis of Soviet *theories* and the qualitative tests leave much to be desired. (See Rovinskii[4]).

The theory of the X-ray technique for measuring the bond strength from X-ray intensity data has been worked on both in the USSR and in the US. The present status of the method is that semiquantitative values of average lattice distortion can be measured; however, local distortions may be quite variable and no theory exists for their determination. The work of Borovskiy[50] represents a good attempt to obtain such a value and is a competent piece of work. It should be noted that it is not successful in developing a general quantitative argument.

In summary, this portion of the work stands in the position of American research on solution hardening of 1936 to 1946. The results are correlatable on several schemes, but no quantitative a priori calculations can be made.

In the field of diffusion great emphasis is placed on the relation of diffusivity to high temperature strength and stability. The primary emphasis appears to be the establishment of a correlation between the activation energy for diffusion with *bond energy*. Actually, the concept of bond energy is a quite nebulous and an undefined parameter. In reality, the diffusion parameters are correlated with such properties as mechanical strength, shift in X-ray absorption edges, amplitudes of thermal vibration, lattice parameters, melting points, etc., which in turn are somehow related to interatomic binding.

It is to be emphasized that these correlations are purely empirical in nature, and no attempts are made to suggest possible mechanisms to account for the observed interrelations. Furthermore, even the validity of some of the correlations must be considered doubtful because of questionable experimentation.

These papers can perhaps best be characterized as representing the engineering approach of making measurements on many complex, commercial alloys and drawing empirical correlations therefrom; in contrast to the scientific approach of attempting to understand the fundamentals of the diffusion process and of exploring possible models and mechanisms for the role of diffusion in other processes.

Theories of high temperature strength

The strength of metals at high temperatures has been explained by many Soviet workers (See for example Dekhtyar[10]) on the basis of vacancy or defect models similar to those of Herring and Nabarro. They find this attractive because of the correlation between high temperature strength and melting temperature and heat of melting. The main hypothesis is that deformation of the metal involves local distortions similar to melting so that such correlations should be valid.

The works of Mirkin[25] and Oding[24] represent departure from this idea. Oding presents a dislocation model of creep, but, in some aspects, the model is rather oversimplified. In no case does he consider recovery processes in the detail which seems necessary to a proper understanding of creep behavior.

The theories rely primarily on observations of macroscopic parameters and little on microscopic observations. The work so far reported is similar to that of Grant, Wood and McLean of eight to ten years ago (See for example Yakovleva[25]). In no case are the models developed capable of quantitative verification or critical testing.

Metallography, phase diagrams and high-temperature strength

The work of Kornilov and co-workers[1, 15, 23] represents a voluminous contribution to the literature relating composition and properties. While correlating the high-temperature strength with composition, in a manner similar to Nisbet and Hibbard, Kornilov derives certain principles of alloying. The so-called *complexity effect* has been observed by many others. The work of Kornilov on complex alloys does not shed any light on the nature of this effect or its origin. The preoccupation of the work with composition leads to a neglect of the structural aspects of high temperature strength. This fault is remedied by the works of Bagaryatski and Tyapkin[26] and Livshitz et al[17, 29] which do a very creditable job of observing the structural changes in high-temperature alloys on aging.

The work of Kornilov covers a wide range of systems and permits qualitative correlation and description of strength. The approach is comparable to that of Hume-Rothery on alloying and compounds. It is not at a stage yet where reliable calculation or prediction in unknown systems is possible. It suffers as all such theories do when no attention is paid to the microstructural effects.

Note: Kornilov's use of a centrifugal testing method does not permit direct quantitative comparison with standard creep tests. This is a serious handicap in evaluating his results.

An example of high quality research work is that of Savitskiy[27] on the brittleness of Cr. This research compares favorably to that of Wain in Australia, Sully in England, and Smith and Seybolt in the US. The conclusion that very high purity chromium is required for ductility is reasonable.

Summary

The main conclusions to be gained by this study is that, while the Soviet metallurgists may have produced a great mass of data and correlations, they are no nearer a satisfactory understanding of high-temperature strength and alloying. The results show some capable work, but nothing new or creative. In many areas the work is only at the stage where Western workers were five to ten years ago. The Soviets do have the advantage of the existing literature on which to build.

Unless their approach to the problem is directed more toward a better understanding of mechanisms and the effects of structure, we can expect no creative contributions in this area; they have the necessary manpower to produce much more information than Western metallurgists can. None of the discussion presented deals with alloy development or production, which may, in some cases, be the sticky part of the problem. It would be interesting to know the problems the Soviets encounter in translating laboratory results to industrial production.

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ROLL-COMPACTING PRODUCES PURE NICKEL STRIP

Nickel strip with excellent mechanical properties has been prepared by roll-compacting pure nickel powders, sintering, and re-rolling the sintered compact. This study of processing variables and their effect on properties indicates good possibilities for adoption of this technique on a commercial basis.

by J. A. Lund

The possibility of producing metal strip by the continuous compacting of powders has been the subject of considerable interest and of patents dating back to 1902. However, the first reported experimental work on the direct rolling of metal powders into continuous dense strip was that of Naeser and Zirm in 1950.[1] These workers rolled atomized iron powders between two cold rolls set in the same horizontal plane. The resulting porous but coherent strip was sintered and rerolled cold to develop full density. A final product was obtained which had mechanical properties at least as good as those reported for strip of the same composition which had been rolled from ingot.

Frannsen[2] has described the commercial application of Naeser and Zirm's method to the production in Germany of copper and copper alloy strip from powders. Storchheim, Nylin, and Sprissler,[3] using 18-8 stainless steel powders, and Evans and Smith,[4] using electrolytic copper powders, have also prepared strip experimentally by this method, and have obtained excellent mechanical properties by suitable control of the roll-compacting, sintering, and re-rolling variables.

The present work

In the work described in the present paper, Naeser and Zirm's method has been applied to the direct rolling of strip from pure nickel powders produced by the Sherritt Gordon hydrogen-precipitation process. The obvious advantages of being able to produce pure nickel or nickel-base alloy strip by this process are that the impurities introduced in melting and casting operations can be avoided, and a high degree of uniformity of composition and physical properties should be obtainable. Furthermore, nickel, and the metals commonly alloyed with nickel, are now available in suitable powder form at prices which may make this method of producing nickel and alloy strip attractive economically.

Roll-compacting

Three grades of pure nickel powder having different particle size distribution were employed in the present work; their chemical and screen analyses, apparent density, and microhardness are listed in Table I. The powders, the product of hydrogen precipitation from ammoniacal nickel sulfate solutions,[5, 6] have the external *botryoidal* shape shown in Fig. 1. Hardness of the particles as-received was high, but no attempt was made to anneal the powders prior to roll-compacting, nor was a lubricant or other agent added to the powders at any stage.

The rolling mill used for initial powder compacting of the green strip was a Stanat Model TAH-400 powder metal mill equipped with two laterally-arranged 6-in. diam plain cold rolls. Rolling speeds of 10 and 30 rpm, and roll gaps of −.004 in., zero, and +.005 in. were studied. The negative roll gap was obtained by tightening the rolls beyond the point of initial contact (zero gap), and taking up .004 in. of the elastic movement in the assembly. A small hopper, in sliding contact with the upper surfaces of the rolls, was used to feed powder to the gap and to control the width of the strip to 3 in.

Densities

Density determinations were made on strip which had been sintered for 5 min at 2250°F. The brief sintering operation was found to be necessary to permit the brittle green strip to be cut into rectangular specimens with regular edges. Values quoted in this report as *green density* are therefore slightly higher than true as-compacted values.

Average density of the green strip varied with roll gap, rolling speed, and grade of powder, as shown in Fig. 2. High density was favored by small roll gaps and fine powder particle sizes. Higher rolling speeds gave lower density strips from F-100 and M-100 powders at all roll gaps, the results being greater with the finer of the two grades of powder. The effect of rolling speed with C-50 powder was variable.

Over the range of the variables investigated, the green strip densities obtained were between 77 and 87 pct of the reported theoretical density of pure nickel.

Density variations across the width and along the length of the strip ranged within ±3 pct of the average value. These variations could not be related to roll gap or speed, but they were less severe in strip prepared from F-100 powder than in mate-

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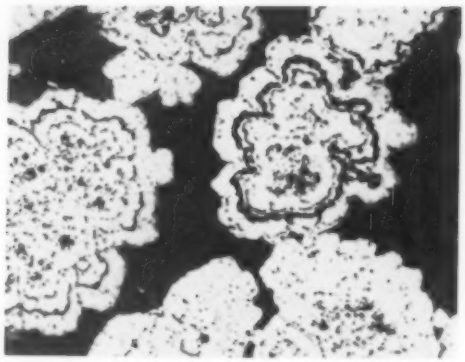


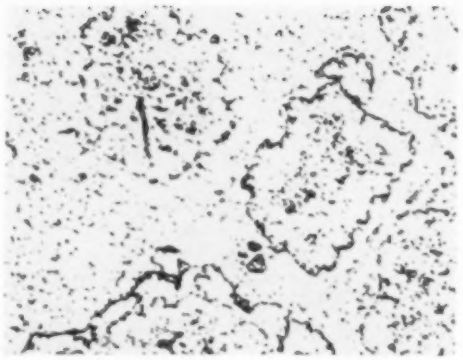


Fig. 1 (left) F-100 nickel powder as received, 450X. Fig. 3 (right) Green strip, roll-compacted at 10 rpm from F-100 powder with −0.004 in. roll gap, 600X; rolling direction horizontal and rolling plane perpendicular to plane of paper.

rial rolled from C-50 and M-100 powders. The distribution of the density variations followed no consistent trends.

Roll pressure

The compacting pressure of the rolls for a given roll gap, speed, and powder grade was estimated by comparing the density of the green strip with the density of thin compacts pressed statically at known pressures from the same powders. A 100-ton capacity press and a floating die set were used to compact specimens from each type of powder, using a wide range of pressures. Roll-compacting pressures were found to vary from 80,000 psi for C-50 powder with +.005 in. roll gap, to 150,000 psi for F-100 powder with −.004 in. roll gap and 10 rpm. Fig. 3 shows the microstructure of green strip which was rolled under the latter conditions. Apparently, very little plastic deformation of the powder particles occurred during compacting. Some fragmentation of particles may have occurred at the higher pressures, the broken fragments serving to fill much of the void space between the larger intact particles.

All green strip produced was coherent throughout its length and showed no cracking. Mechanical strength and stiffness were greatest in strip of high density, but flexibility (or the ability to stand up to an operation such as coiling) was greatest in the lower density strip.

Densification of sintered green strip

Samples taken from all green strip produced in the experiments just described were sintered for 15 min at 2250°F. Each was then cold re-rolled and annealed four times, using single passes and an annealing treatment of 25 min at 1600°F after each pass.

All sintering, annealing, and cooling operations were carried out in a 15 kw molybdenum-wound Drever muffle furnace, with an atmosphere of dissociated ammonia.

Cold re-rolling was performed on a Stanat Model TA-215 combination mill, equipped with plain ¾ in. diam work rolls and 4-in. diam back-up rolls. Only the lowest of four available speeds (35 linear ft per min at the work rolls) was used in the present work.

The roll gap used for each pass was kept constant:

1st pass,	+ .015	in. gap
2nd pass,	+ .010	in. gap
3rd pass,	+ .005	in. gap
4th pass,	Zero	gap

The reduction in thickness received by each strip was thus dependent on the prior thickness and density of the strip, and had to be determined at each pass for all strips.

Table II contains the results of density measurements on sintered strip at each stage of the densification program. The wide scatter of results after the first cold-re-rolling has been partly attributed to

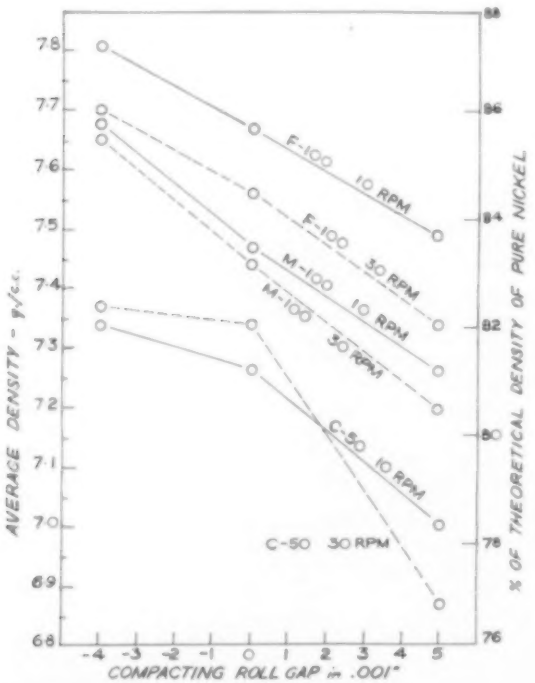
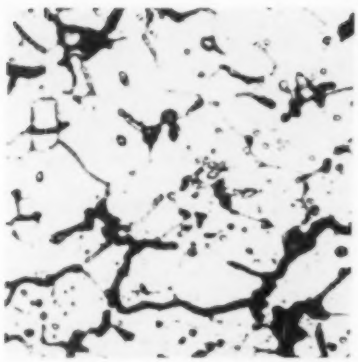


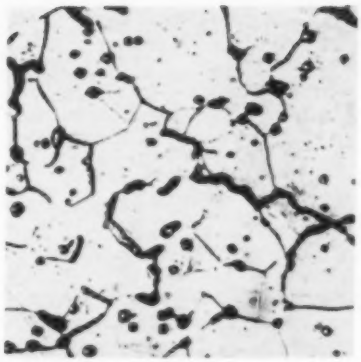
Fig. 2—Variation of green strip density with compacting roll gap, roll speed, and grade of nickel powder.

Table I. Properties of Nickel Powders Used

Typical Properties		Grade[1] C-50	M-100	F-100
Screen Analysis, pct:	−80 + 100 mesh	1	nil	nil
	−100 + 150 mesh	32	4	1
	−150 + 200 mesh	61	45	8
	−200 + 250 mesh	2	42	26
	−250 + 325 mesh	2	8	37
	−325	2	1	28
Chemical Analysis, pct:	Ni + Co	99.9	99.9	99.9
	Cu	0.02	0.04	0.03
	Fe	0.02	0.04	0.05
	S	0.015	0.018	0.020
Approx. apparent density, g per cu cm		4.2	3.9	3.6
Microhardness (V.H.N.): as received		240/280	240/280	240/280

[1] All powders supplied from production lots by Sherritt Gordon Mines, Ltd., Fort Saskatchewan, Canada.





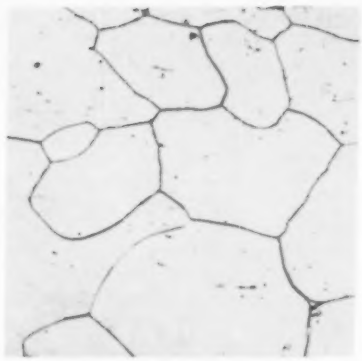


Fig. 6 (left) F-100 strip, compacted and sintered at 1900°F for 30 min, 600X. Fig. 7 (center) F-100 strip, compacted and sintered at 2250°F for 15 min, 600X. Fig. 8 (right) Fully densified and annealed F-100 strip (99.5 pct of theoretical density), 800X.

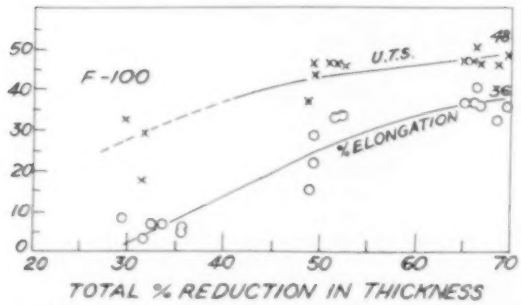


Fig. 4—Effect of cold re-rolling and annealing on tensile strength and elongation of sintered strip from F-100 nickel powder. Ordinate shows ultimate tensile strength in 1000 psi and pct elongation.

density differences in the green strip, which themselves originated from different roll-compacting conditions. Thus, material which had the lowest density after roll-compacting and sintering still had the lowest density after the first cold reduction. After the fourth pass, a large scatter in density values was again obtained. Also, whereas annealing after the second and third reductions produced a significant increase in density over the as-rolled value, the reverse was invariably the case after the fourth cold reduction.

Tensile properties

Tensile strength and elongation measurements were made on a Hounsfield Tensometer, using ASTM standard tensile test specimens for sheet. The results for strip at the second, third, and fourth stages of the densification cycle are plotted in Fig. 4.

Maximum properties attained by strip from M-100 and F-100 powders compare favorably with those reported in the ASM Metals Handbook for cast, wrought, and annealed pure nickel.

The decrease of density which followed the fourth cold reduction and annealing was not reflected in a loss of mechanical properties. Both ultimate strength and elongation rose significantly between the third and fourth stages of the densification cycle.

Fig. 5 shows the effect of further cold rolling on the tensile strength and pct elongation of densified and annealed strip. The strip was prepared originally from F-100 powder, compacted with zero roll gap and 10 rpm roll speed, sintered 15 min at 2250°F, and reduced 50 pct in thickness by cold re-rolling in two passes, with intermediate and final annealing treatments of 25 min at 1600°F.

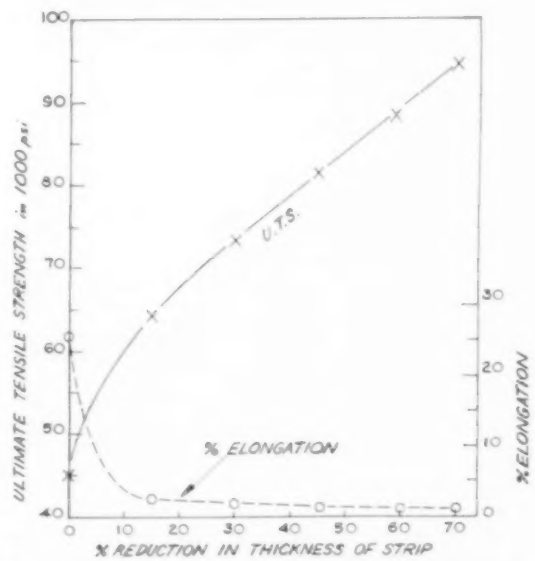


Fig. 5—Effect of cold rolling on tensile strength and elongation of densified strip. F-100 strip, sintered 15 min at 2250°F, cold rolled 50 pct, annealed 25 min at 1600°F, then re-rolled by amounts indicated.

A separate experiment was conducted to determine whether or not lower temperatures than 2250°F were practical for sintering green strip to provide suitable material for cold-re-rolling.

Green strip was compacted from F-100 powder using zero roll gap and 10 rpm roll speed. The following sintering temperatures and times were used: 2250°F for 15 min; 2000°F for 15, 30, and 60 min; and 1900°F for 15, 30, 60, and 120 min. All sintered strip was reduced 30 pct in thickness by cold rolling, and then annealed for 25 min at 1600°F. The results of tensile strength and elongation determinations on the finished strip thus produced are collected in Table III.

The results of this experiment may be summarized as follows:

(a) Sintering for 15 min at temperatures of 1900° and 2000°F gave properties after cold-rolling almost comparable to those of strip sintered for the same time at 2250°F;

(b) A tensile strength of 46,000 to 48,000 psi could be developed with only 30 pct reduction of strip sintered for 30 min or more at 1900° and 2000°F. Longer sintering times at these tempera-

tures did not produce an appreciable improvement in properties after cold rolling and annealing;

(c) Per cent elongation of strip which was cold worked 30 pct after sintering for 30 min or more at 1900° and 2000°F was superior to that of strip which had been similarly worked after sintering for 15 min at 2250°F.

The as-sintered microstructures of strip sintered at 1900°F for 30 min, and at 2250°F for 15 min are reproduced in Fig. 6 and 7. Two processes appear to be involved in the sintering operation: densification due to sealing of the voids between powder particles, and grain growth. Both processes are favored by higher temperatures and times, but large grain size has a deleterious effect on properties when the residual porosity after sintering is chiefly concentrated at the grain boundaries. Comparing the structures shown in Fig. 7 and 8, there is a more continuous path of porosity along the boundaries of the large grains in the latter, even though the total amount of porosity in both structures is comparable.

Fig. 8 shows the typical microstructure of roll-compacted strip after sintering and densifying to develop high tensile strength and elongation.

Discussion

The green density of roll-compacted nickel strip appears to have very little influence on the properties which can be obtained finally after sintering and densifying by a given amount of cold re-rolling. This indicates that particle size, roll gap, and roll speed are relatively unimportant compacting variables in terms of the quality of the final product. However, the physical characteristics of the green strip would be important in a commercial application of this process, since the strip would have to be coiled or otherwise handled. Qualitatively, the highest density green strip was the strongest, but was also the least flexible within the range investigated. It is felt that optimum handling characteristics would be exhibited by green strip of intermediate density, such as was obtained in the present work using F-100 powder with a roll gap of +.005 in., or M-100 powder with zero roll gap.

Poorly compacted edges and density variations encountered in green strip would be undesirable if the process were to be applied on a commercial basis. Poor edges are the result of the lateral flow of powder in the roll gap, and it is known that in practice, strip with firm edges can be obtained by modifying the roll design and feeding arrangements. Density variations along the length and across the width of the green strip could be overcome by insuring a uniformly-distributed and constant flow of powder to the roll gap. Vibration of the hopper, or of the powder in the roll gap, would also promote uniform strip density by reducing the tendency of powder particles to *bridge* in the gap.

Sintering temperatures and times were not investigated extensively in this work. However, the results contained in Table III indicate that fairly rapid sintering does occur in roll-compacted nickel strip at temperatures as low as 1900°F, and that there is an optimum sintering time beyond which little improvement of the strip properties is experienced on subsequent cold-working.

In the densification cycle used for the bulk of the present work, four cold reductions and annealing treatments were employed. The results of Table III, however, are for material which was densified in a single cold rolling and annealing operation. This suggests that not more than two reductions of 20 to 30 pct each would be required to obtain optimum properties in strip produced by this process.

It is likely that hydrogen was absorbed by strip from the furnace atmosphere during annealing treatments. This may have resulted in the formation of fine microporosity when entrapped hydrogen was precipitated from solution in rapidly cooled strip, especially in the case of denser material from which the escape of hydrogen to the surface would require longer times at elevated temperatures. Such microporosity could account for the variations of strip density which were observed in the last stages of the densification cycle. Mechanical properties of the strip, on the other hand, would likely be less affected by spherical gas porosity than by the stress-raising interparticle porosity which existed prior to the last cold reduction.

Conclusions

The results of this work indicate that the production of pure nickel strip by the continuous roll-compacting of hydrogen-precipitated nickel powders, followed by suitable sintering and cold rolling operations, is practicable, and that the mechanical properties of strip produced by this process are at least comparable to those of cast and wrought nickel in the same temper condition.

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Table II. Density of Strip at Various Stages of Densification

	C-50 Strip	M-100 Strip	F-100 Strip
First Cold Reduction			
Reduction from Green Thickness, pct	5-12	6-11	12-17
Density, As-Rolled, g per cu cm	7.53±.18	7.89±.10	8.10±.12
Density, Annealed, g per cu cm	7.51±.24	7.88±.17	8.06±.12
Second Cold Reduction			
Reduction from Green Thickness, pct	21-30	23-31	29-36
Density, As-Rolled, g per cu cm	7.93±.07	8.25±.05	8.41±.07
Density, Annealed, g per cu cm	8.07±.09	8.36±.06	8.49±.08
Third Cold Reduction			
Reduction from Green Thickness, pct	39-46	42-47	48-53
Density, As-Rolled, g per cu cm	8.58±.06	8.60±.05	8.63±.09
Density, Annealed, g per cu cm	8.61±.06	8.67±.05	8.68±.15
Fourth Cold Reduction			
Reduction from Green Thickness, pct	60-64	61-65	64-70
Density, As-Rolled, g per cu cm	8.64±.19	8.82±.18	8.82±.14
Density, Annealed, g per cu cm	8.63±.13	8.62±.12	8.69±.10

Table III. Effect of Sintering Temperatures and Time on Compacted F-100 Powder

Sintering Temp, °F	Sintering Time, Min	Properties After Cold-Work and Anneal[1]	
		UTS, Psi	Pct Elongation (in 2 In.)
2250	15	34,300-36,900	8-15
2000	15	29,000-36,900	7-10
2000	30	43,000-46,700	17-23
2000	60	44,500-47,100	21-27
1900	15	28,000-38,800	6-15
1900	30	40,000-48,200	16-27
1900	60	43,800-47,800	17-26
1900	120	43,200-48,700	17-28

[1] All ranges of values based on 5 and 6 determinations of each property.

VACUUM SPECTROSCOPY GIVES RAPID STEEL ANALYSIS

By sparking samples in an inert atmosphere and analyzing spectra in a vacuum, it is possible to analyze iron and steel for C, P, and S, in addition to those elements determined in older units. Application of basic spectroscopy principles are reviewed, and the Quantovac, a vacuum spectrograph which gives rapid analysis for all important elements, is described.

by Charles L. Winchester

OPTICAL emission spectroscopy provides one of the most rapid, accurate, and precise methods of elemental analysis available to the modern engineer or scientist. Although wet chemical analysis is still the mainstay of many laboratories, modern emphasis on fast and accurate results, involving a minimum of effort, has dictated the present trend toward the use of spectrochemical procedures.

Spectroscopy fundamentals

The science of optical emission spectroscopy is based on the physical concept that an element emits light of characteristic wave length when volatilized by means of a flame or electrical discharge. This photon radiation generally originates in energy changes of the valence electrons of the atoms in the sample. Only those elements with low excitation energy requirements (alkalis, alkaline earths) can be excited in a flame, while electrical discharges at a reduced pressure are needed to excite elements with high excitation energies (rare gases and halogens). The majority of the elements can be excited by arc or spark discharges in air, and these discharges are used for routine, high-speed analysis. This is facilitated by the fact that the intensity of the emitted light is often directly proportional to the amount of the element present.

Three basic components are required for a spectrochemical analysis: 1) a means of volatilizing the sample, 2) a system of optics for dispersing the different wave lengths of light produced, and 3) a means of determining the intensity of the light produced by each element of interest. A spectrograph records each wave length on a photosensitive film or plate, the intensity of the radiation being subsequently determined with a densitometer.

Although more than 70 elements can be analyzed on conventional direct-reading equipment, some important elements cannot be included because their characteristic wave lengths are so short as to be absorbed by oxygen in the air. This phenomenon occurs at wave lengths shorter than 1900A, in the far ultraviolet spectrum. This region is of particular importance to the iron and steel industry, since sensitive arc lines of carbon, phosphorus, sulfur, and other important elements are found here.

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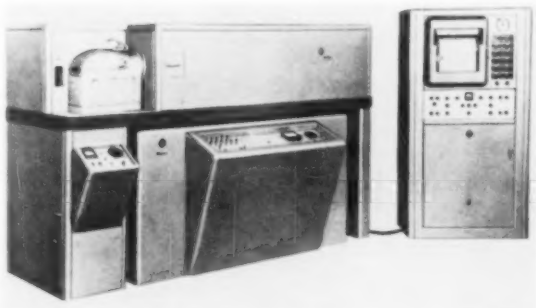

Fig. 1—The Quantovac spectrometer with the ARL Multisource unit and the recording console.

In order to detect these elements, air must be eliminated from the optical path of the instrument. This can be accomplished either by using a vacuum or by displacement of air with another gas of greater transparency. A combination of these two practices can also be used, provided windows of high transparency are available. Fortunately, several window materials suitable for the range above 1600A are available; lithium fluoride, calcium fluoride, and quartz of 2-mm thickness permit transmission of greater than 90 pct of all radiation in this spectral range.

In addition to the requisite of a transparent optical path, two other problems exist in the design of a practical instrument for far ultraviolet spectroanalysis: 1) there must be rapid means of introducing samples to the instrument, and 2) excitation conditions close to optimum must be provided, if the inherent sensitivity of the spectrochemical method is to be utilized. The first problem is solved by using a small enclosed arc-spark stand, wherein the air introduced by the loading of the sample, is displaced by simple flow of a transparent gas at atmospheric pressure. Commercially pure argon is quite satisfactory for this purpose in the analysis of carbon and low-alloy steels.

Table I. Spectrum Lines Handled by the Quantovac Suitable for Steel Analysis

1775A	P	2714A	Fe
1807A	S	2775A	Mo
1890A	As	2933A	Mn
1931A	C	3082A	Al
2316A	Ni	3110A	V
2516A	Si	3175A	Sn
2677A	Cr	3242A	Ti
		3274A	Cu

Table II. Concentration Ranges Analyzed by Quantovac

Element	Concentration Range, Pct
P	0.001 to 0.15
S	0.001 to 0.10
C	0.003 to 2.25
Ni	0.01 to 3.00
Si[1]	0.01 to 1.00
Cr	0.01 to 8.50
Mo	0.01 to 1.00
Mn	0.01 to 1.50
Cu	0.01 to 1.00

[1] High silicon concentration requires a more spark-like discharge to excite the sample properly.

Table III. Data on Precision

Element	Avg Concentration, Pct	Coefficient of Variation	Number of Determinations
Cr	0.05	2.8	10
	0.55	0.65	19
	3.00	0.37	10
Ni	0.29	1.1	19
	0.56	1.2	10
C	0.075	3.1	19
	0.24	1.3	10
	0.80	1.2	8
	1.00	0.7	10
Mn	0.34	1.3	19
	0.88	0.8	10
Mo	0.01	8.0	19
	0.90	1.1	10
Cu	0.11	11.8	10
	0.36	1.7	19
Si	0.019	13.2	10
	0.35	1.1	19
P	0.022	3.3	10
	0.086	2.4	19
S	0.019	3.5	10
	0.042	2.4	19

Table IV. Data on Accuracy

Element	Concentration Range, Pct	Percentage of Element, Avg Deviation from Chemical	Percentage of Element, Max Deviation from Chemical	No. of Samples
Cr	0.02 to 1.75	0.009	0.030	58
	1.76 to 8.45	0.019	0.05	11
Ni	0.02 to 1.76	0.008	0.030	53
C	0.05 to 0.20	0.005	0.017	51
	0.21 to 0.80	0.009	0.025	13
	0.81 to 1.31	0.018	0.030	11
Mn	0.11 to 1.11	0.010	0.027	65
Mo	0.03 to 0.80	0.011	0.035	49
Cu	0.02 to 0.26	0.086	0.025	40
Si	0.04 to 0.62	0.014	0.032	32
P	0.005 to 0.025	0.0017	0.006	28
S	0.01 to 0.04	0.0026	0.005	19

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Thus, a satisfactory system can be designed by using argon in the arc-spark stand, lithium fluoride or calcium fluoride window between the stand and the spectrometer, vacuum in the main body of the spectrometer, and finally, quartz as the windows for the multiplier phototubes.

The Quantovac

An instrument called the Quantovac has been designed and manufactured in accordance with these principles by Applied Research Laboratories, Inc., Glendale, Calif. Fig. 1 shows the Quantovac spectrometer with the ARL Multisource unit located beneath it and the recording console as a separate component. The Multisource provides versatile excitation which is effective in most analytical situations. A mechanical vacuum pump is located in the lower left portion of the spectrometer section. The instrument is ready for analysis when the pressure has been reduced to the relatively poor vacuum of 15 microns.

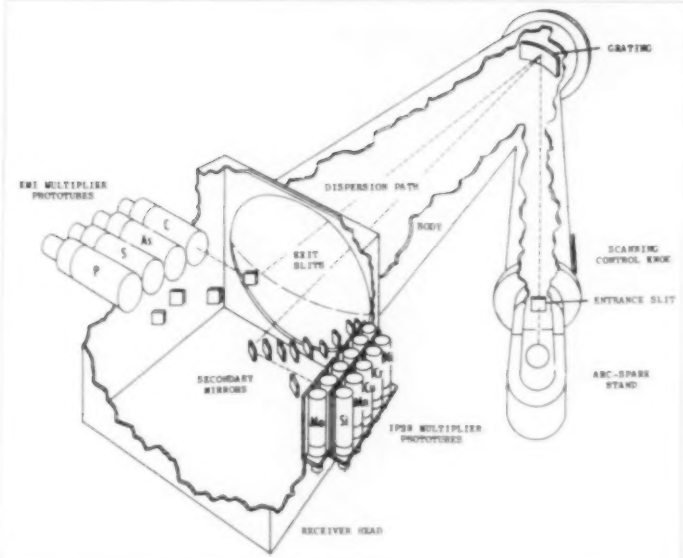
Samples for analysis may be cast, or forged. Homogeneity and proper deoxidation are important to avoid porosity, with its attendant entrapment of oxygen and nitrogen. In the technique developed by the Applied Research Laboratories for carbon and low alloy steels, the samples are dried and heated to about 70°C prior to each sparking in order to promote the apparently greater electron mobility achieved at higher temperatures.

A single, low-voltage, spark-initiated, intermittent arc discharge has been shown to provide high-speed, routine control on production samples of carbon and low alloy steels. Ignition of the 3-mm gap is provided by means of a high-voltage circuit and rotary gap switch operated once every cycle of the input power.

A diffraction grating is mounted inside of the evacuated spectrometer for dispersion of the incident light beam into its wave length components. Extensive studies have indicated optimum performance from a grating of 24,400 lines per in. and 1.5-m radius of curvature. Since spectrum lines of interest are centered in the 1700A to 1950A range, the grating is blazed to favor this region. Consideration of the fields of greatest application has resulted in the production of an instrument possessing a range of 1800A with a reciprocal linear dispersion of 6.97A per mm in the first order. By allowing the grating to be positioned at different points along the axis of the tube, and to be deflected so that its normal is at various positions at the receiver end of the spectrometer, any range of 1800 between 1100A and 3500A may be utilized for specific application. In analyzing steel and cast iron, for example, this allows a very important range from 1700A to 3500A to be covered in a single instrument.

In order to control spectrum drift which might result from temperature gradients within the optical path, the spectrometer is encased in polyurethane insulation. This 1-in. thick plastic foam holds the temperature within the spectrometer nearly constant so that spectrum drift is reduced to negligible proportions.

Light dispersed by the grating is focused on secondary slits mounted in the slit frame on the Rowland circle. Beams of monochromatic light of wave lengths characteristic of the elements of interest pass through the slits and impinge upon secondary mirrors mounted in the receiver head, Fig. 2. From here, the beams are directed onto sealed quartz



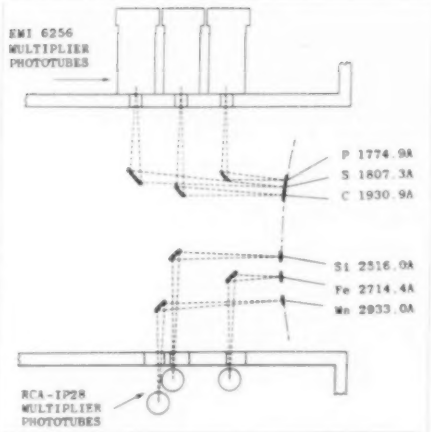


Fig. 2. (left) Inside of the Quantovac.

Fig. 3 (above) A typical array of elements which may be analyzed in steel and cast iron.

windows which terminate the vacuum path. The quartz windows allow radiation with wave lengths longer than 2100A to pass through air to IP 28 multiplier phototubes, while wave lengths shorter than 2100A enter directly into 13-stage EMI multipliers. As many as 23 phototubes can be accommodated in the receiver head, thus permitting simultaneous analysis of a maximum of 23 elements.

Each phototube is connected to an integrating capacitor, which is charged to a dc voltage proportional to the intensity of the photon radiation entering the phototube. All capacitors are charged simultaneously. At the end of the integration time (controlled by the intensity of the internal standard line) the phototubes are disconnected, and the electrometer amplifier is connected to the integrators one at a time. When a particular integrator is connected to the amplifier, the associated zero and sensitivity controls are also connected into the circuit. Thus, the voltages on the simultaneously-charged integrators are read sequentially at the rate of one every 2 sec, the results being traced on special chart paper by a recorder. A digital voltmeter and electric typewriter combination form an alternate readout system. In this way, an entire analysis is provided by the Quantovac in less than 2 min.

Application, accuracy, and precision

Fig. 3 is a diagram of a typical array of elements which may be analyzed in steel and cast iron. Listed in Table I are a number of the more frequently used spectrum lines that can be included in the Quantovac.

In general, broad concentration ranges of elements in various steel alloys can be analyzed by the Quantovac. Table II lists concentration ranges of several important elements in carbon and low alloy steels which have been determined by this method.

Standard samples are used for the preparation of the analytical curve for each element being analyzed. For example, in the analysis of low alloy steels, eight disk-type standards are available from the National Bureau of Standards. They can be applied directly to spectrochemical analysis of ladle and heat test samples of low alloy steels. They should, however, be re-evaluated locally to correct for metallurgical differences between samples and standards.

The reproducibility of determinations made with a given lower electrode and a given sample under identical conditions provides a measure of precision. Extensive investigations of both precision and accuracy have been conducted by Applied Research Laboratories' analytical methods group. The results of these investigations have established coefficients of variation for the determination of nine elements found in carbon and low alloy steels as given in Table III. The coefficient of variation, v, is calculated as follows:

$$v = \frac{100}{C}\sqrt{\frac{\Sigma d^2}{n-1}}$$

where C = Avg concentration, in pct,
d = Difference of determination from the mean,
n = Number of determinations.

In general, the coefficient of variation is less than 1 for concentrations above 1.0 pct. For concentration between 0.1 and 1.0 pct, the coefficient of variation ranges from 1.0 to 3.0, whereas for concentrations below 0.1 pct, coefficients of variation of 3 to 10 can be expected.

A comparison of chemical and spectrochemical determinations on a number of samples for nine elements found in carbon and low alloy steels is given in Table IV.

Conclusions

It has been demonstrated that lines of good sensitivity are now available for the spectrochemical analysis of carbon, sulfur, and phosphorus. This means that for many metallurgical control programs the whole job of analysis can now be done by a single high-speed, direct-reading spectrochemical means. From a single ferrous sample, all important alloying elements can be determined automatically, quickly, and economically by a machine such as the Quantovac. Precision and accuracy are shown to be unsurpassed by other routine analytical methods.

BERYLLIUM

Its Problems and Possibilities

Report of the Panel on Beryllium
Summarized by Joseph R. Lane,
Staff Metallurgist, Materials Advisory Board

Organized by the Materials Advisory Board, a unit of the National Academy of Sciences —National Research Council, the study on beryllium was sponsored by the US Dept. of Defense.

The following members comprised the Panel on Beryllium (Physical Metallurgy Group)

Chairman: Albert R. Kaufmann
Nuclear Metals, Inc.

R. L. Fullman
General Electric Research Lab.

George A. Hoffman
The Rand Corp.

F. D. Jewett
The Martin Co.

Walter R. Lowry
The Beryllium Corp.

J. M. Simmons
US Atomic Energy Commission

(alternate for Mr. Simmons)
R. E. Pahler
US Atomic Energy Commission

C. W. Schwenzfeier, Jr.
The Brush Beryllium Co.

Government Liaison

R. R. Kennedy, Wright Air Development Center
D. H. Kleppinger, Frankford Arsenal
R. Schmidt, Bureau of Aeronautics

There is a great incentive for the saving of weight in airframe structures, and there is reason to believe that beryllium could qualify as a highly desirable structural material. Nevertheless, no such use has been made, at least until recently. This report attempts to explain why this is so, and what the prospects for future use may be.

UNTIL about ten years ago, beryllium metal was generally considered to have practical utility only as a nuclear material. Even in the nuclear engineering field, its uses were severely limited by the fact that the only forms in which the metal was available were lumps, granules, and small castings of poor physical properties, and by the fact that the machining of the castings was difficult and costly.

By 1950, powder metallurgy techniques had displaced casting almost completely for producing the billets and blocks that are the starting materials from which finished metal shapes are fabricated. The fine grain size of the powder metallurgy billets increased the ductility and malleability of the metal sufficiently to permit machining of beryllium into parts of very intricate design to the highest standards of precision.

Pure beryllium in the forms available today does not have the ductility of the common light metals, nor does it appear likely that this desirable characteristic will be achieved in the near future. Offsetting the lack of ductility, however, are beryllium's outstanding physical properties of low density, high strength to density ratio at room and elevated temperatures, high specific heat, and its very high modulus of elasticity. Beryllium's possession of these properties and its limited availability now in a number of sizes and shapes entitle pure beryllium metal to consideration among the other modern engineering materials.

Beryllium, at present and in the foreseeable future, is relatively costly to buy and expensive to fabricate. In spite of the advantages that may be claimed for general use of beryllium in airframe structures, the high cost of raw material and fabrication procedures will place a practical limit on its use.

Availability of ore

A group on the Beryllium Panel itemized known deposits of beryl and the accompanying costs of recovering a commercial concentrate from them. It was indicated that an annual production of nearly 800 tons of contained beryllium can be expected from sources outside the US at a price of $3 per lb of contained BeO. Production of beryl from domestic deposits has always been small, approximately 20 tons contained beryllium annually. A large production of beryllium from known sources in the US and Canada can only be accomplished by milling low-

grade pegmatite ores. However, costs are estimated at $5 to $33 per lb with the average nearer the higher figure.

The considered opinion of the group is that the development of major new sources of beryllium is within the bounds of possibility, and that price incentives would contribute to this. However, major developments are likely only over a long period, and only if sustained efforts are made along the lines of research in extraction and in the factors that govern the occurrence of beryllium in the earth's crust.

Ductility problem

Metallic beryllium has been prepared and studied by many people throughout the world. All of them have found beryllium to be relatively brittle, and this shortcoming has been the chief deterrent to the use of beryllium for structural purposes.

Composition: Beryllium of commercial purity contains about 0.1 pct Al, 0.1 pct Fe, 0.05 pct Si, 0.2 to 1.0 pct O_2, and approximately 0.005 to 0.01 pct of other common metals, such as Cu, Ni, and Cr. A number of studies in the past have indicated that beryllium which is substantially purer than the above does not have noticeably different properties.

Forms of Beryllium: Commercial beryllium can exhibit widely different values for ductility in tension at room temperature, depending upon its method of fabrication, grain size, and preferred orientation. These differences occur with no significant change in impurity content other than variation in the amount of oxygen. This variation in oxygen above the solubility limit (which is exceedingly low) appears to have no effect on the results.

Vacuum-cast beryllium has the lowest oxygen content of any commercial form and is the most brittle, having essentially zero ductility at room temperature. An extrusion made from such a casting will exhibit 2 pct to 3 pct elongation in tension and 20 pct contraction in compression. This improvement may be attributed to refinement of grain size and development of a texture. Vacuum-cast beryllium may be converted to powder and reformed by various powder metallurgical techniques. Such material exhibits 1 pct to 2 pct elongation. As a result of making powder, the oxygen content is increased from about 0.2 wt pct to about 1.0 wt pct. Powdered beryllium, if extruded at about 1900°F, exhibits 15 pct to 20 pct elongation in the extrusion direction. The preferred orientation appears to be identical with that which is achieved in extruded cast beryllium.

Powdered beryllium may be formed into sheet by various procedures which produce a highly developed texture, wherein the basal planes are all close to the plane of the sheet. Such material, if processed under optimum conditions, can exhibit 30 pct to 40 pct elongation under conditions of uniaxial strain in any direction in the plane of the sheet. In the thickness direction the ductility is very low, and as a result, a biaxial tension strain readily leads to fracture.

Effect of impurities on brittleness

A great many people have studied beryllium and tried to make pure forms of it in order to achieve ductility. The net result of this work was the general conclusion that removal of impurities would not make beryllium a ductile metal.

Nonmetallic Impurities: It is conceivable that oxygen could lead to brittleness in beryllium as it does in titanium and zirconium and a number of other metals. It has not been possible to date to determine whether oxygen is measurably soluble in solid beryllium or to identify an oxide phase. Numerous attempts have been made and are still being made to produce oxygen-free beryllium by special procedures, such as distillation in high vacuum, electrolysis from organic compounds of beryllium, thermal decomposition of beryllium iodide, and vapor phase reduction of beryllium chloride with sodium.

It is also conceivable that nitrogen and carbon might embrittle beryllium. As far as is known, this question has not been extensively explored. The most that can be said is that some samples of beryllium containing less than 0.05 wt pct N and C did not exhibit unusual ductility.

Metallic Impurities: Work in the last ten years has not drastically changed the opinion of early investigators that removal of metallic impurities will not lead to increased ductility.

Recent work shows definitely that iron additions up to 0.5 wt pct progressively reduce the elongation of *ductile* sheet. Nickel additions up to the same amount cause less of a reduction, while copper appears to have no effect on ductility. Extrapolation of the ductility curve for iron does not indicate that iron-free beryllium would have remarkably increased ductility. This work was concerned with fracture on the 1120 planes. It is not known what effect, if any, these impurities have on the basal planes.

Possibility of health hazard

No applications of beryllium should be planned without a full appreciation of the toxicity of this metal and its compounds. A Materials Advisory Board Panel on the Toxicity of Beryllium, headed by Professor Harold Hodge of the University of Rochester, has recently prepared a report on this subject, from which the following remarks are abstracted.

In contrast to former beliefs, no reasonable doubt now remains that small amounts inhaled have produced an acute disease (pneumonitis) and/or a chronic disease (granulomatosis), the latter having a high mortality rate. Contact with certain beryllium compounds can produce a dermatitis which may be serious with respect to lost time, but which can be combatted with suitable protective clothing or skin creams.

Protection against beryllium poisoning is largely a matter of controlling the dust evolved in the operations on the metal. As a *target figure* for the average allowable concentration of beryllium in the air, 2 micrograms per cu m may tentatively be acceptable. This does not constitute a guarantee that no chronic illness will develop; there are cases in which a lag time as long as 16 years intervened between exposure and symptoms.

To keep airborne beryllium at the required low level, the following principles are suggested:

1) Manual handling should be reduced to an absolute minimum.

2) Every implement which has been in contact with beryllium should be regarded as contaminated, and therefore, a potential dust source.

3) Every process step should be examined critically to determine whether by arrangement or substitution it can be made less dusty.

4) Essentially every process step must be provided

with some degree of ventilation. The only effective method of control is to contain and remove the dust at its source.

Structural considerations

Since beryllium has been used chiefly in nuclear applications, there has not been a need for many of the mechanical data usually used by aircraft designers. Nevertheless, characteristic strength values are tabulated below in Tables I and II.

Ductility: The attainment of a reasonable amount of ductility in all directions (in turn, not necessarily simultaneously) including the thickness direction is required, if beryllium is to be a reliable structural material for extended use in missiles and aircraft. Without this amount of ductility, only limited applications are likely. Many of these applications would require the generally weaker but more ductile grades, and as a result the gain in performance compared to competitive materials may not be great.

Suitably worked or annealed, beryllium may exhibit substantial ductility in a tensile test. However, this material can fail in a brittle manner if a wide piece of sheet is bent, or stresses occur simultaneously in two directions. The *optimum* preferred orientation responsible for the highest tensile ductility in the plane of the sheet permits no significant deformation in the thickness direction, so the material is unable to *thin down*. As a result, elongation in one direction in the plane of the sheet can occur only if equal contraction is permitted in the perpendicular direction in the plane of the sheet; therefore, the 30 to 40 pct elongation measured in tension on what formerly had been thought to be optimum processed beryllium sheet, may have little or no value in its engineering use. This strongly directional ductility may be incapable of performing the essential engineering function that ductility normally performs.

Ductility, as measured by the plastic elongation just prior to fracture, is the property most in need of improvement to permit widespread beryllium usage in primary structures and powerplants of a flight vehicle.

It is safe to assume that the minimum elongation expected of today's best aluminum alloys will suffice for future structures, and this elongation constitutes a valid indication of the ductility required of beryllium to become of general structural use. This permissible level is as low as 1 pct in extrusion and 1.5 pct in castings, but is no less than these amounts in any direction.

Tensile strength: The ratio of density to ultimate tensile stress has been used to compare the weight of tension structural components made of various metals. These components, designed by tension criteria, abound in missiles and space craft and constitute by weight better than one-third of manned aircraft.

To find what ultimate tensile stress will be required of future beryllium to be competitive with aluminum, titanium, and steel, one must assume a value for the future ultimate tensile stress of these three conventional metals and multiply it by the ratio, density of beryllium: density of conventional material. The results of these calculations are tabulated in Table III for various temperatures.

Compression: Compression buckling criteria govern the design of better than half by weight of the structure of manned aircraft.

When comparing metals used in thin-walled structures designed by buckling criteria, one must distinguish between the various types of construction. For example, when considering sandwich-type panels for low load-intensity structures, it may suffice as a first rough approximation, to specify that the yield compression stress should be about 4/5 of the ultimate tensile stress listed above, to be competitive with the conventional metals.

The method used to obtain the relative weight of sheet-stringer panels at various temperatures gives the lowest yield compression stress required of beryllium.

Temp. °F	Intermediate Load Intensity (q/L_c = 200 Psi)	High Load Intensity (q/L_c = 600 Psi)
70	35,000 psi	55,000 psi
400	30,000	45,000
800	20,000	30,000
1200	10,000	15,000

Comparing the data of the previous section with the properties of present beryllium, it can be seen that hot or warm extruded or warm rolled beryllium is the material of choice (stronger for equal weight) over the temperature range of 70° to 1200°F both

Table I. Tensile and Compression Properties of Beryllium Produced from Powder

	Ult. Tensile Strength, Psi	Yield Strength, 0.2 Pct Offset, Psi	Modulus of Elasticity, Psi	Poisson's Ratio	Pct Elongation in 2 In.	Pct Reduction in Area	Compression Yield Strength, 0.2 Pct Offset, Psi	Compression Modulus of Elasticity, Psi
Vacuum Hot Pressed QMV Beryllium Block	35,000-45,000	25,000-40,000	$42-44 \times 10^6$	0.024	0.5-3.0 pct	0.5-3.5 pct	25,000-35,000	$42-44 \times 10^6$
Hot Extruded Beryllium Longitudinal Properties Extruded at 1000°-1100°C 12:1 Reduction Ratio								
Annealed at 750°C	60,000-100,000	40,000-55,000	$41-44 \times 10^6$	0.032	8-16 pct	—	35,000-40,000	$42-44 \times 10^6$
Warm Extruded Beryllium Longitudinal Properties Extruded at 800°F 5:1 Reduction Ratio								
(As extruded)	85,000-100,000	80,000-90,000	$42-44 \times 10^6$	0.030	0-1 pct	—	85,000	44×10^6
(Annealed at 1400°F	60,000-90,000	45,000-55,000	$42-44 \times 10^6$	0.030	2-5 pct	—	50,000	43×10^6
Hot Rolled Beryllium Sheet (1650°F) 30:1 Reduction in Area with some cross rolling	Long. 50,000-56,000 Trans. 40,000-55,000	Long. 35,000-50,000 Trans. 35,000-50,000	Long. $41-44 \times 10^6$ Trans. $40-44 \times 10^6$	— —	Long. 1-4 pct Trans. 0.5-2 pct	— —	— —	— —
Warm Rolled Beryllium Sheet (1200-1450°F)								
Longitudinal	80,000-90,000	60,000-70,000	44×10^6	—	5-10 pct	—	—	—
Transverse	80,000-90,000	60,000-70,000	44×10^6	—	5-10 pct	—	—	—

in tension and compression. Hot pressed block is superior to aluminum, titanium, and steel only in the range of about 800° to 1200°F.

Possible design compromises

The level of properties required for conventional construction (sheet-stringer, for example) is well known, and it is recognized that present commercial beryllium is inadequate for the purpose. These standard techniques have evolved because ductile materials were available. While the development of more ductile and stronger beryllium should be pushed, consideration should also be given to the possibility of a wider utilization of present beryllium by adjusting to its limitations.

A simple example can be cited. Beryllium bolts made with standard screw threads will fail readily in a brittle fashion. By changing the thread form to eliminate a sharp notch at the root, however, satisfactory beryllium bolts have been produced.

Production of mill products

Present commercial beryllium is now produced from billets made by powder metallurgy procedures, from which all beryllium parts, sheet, and rod, are fabricated. In the manufacture of powder metallurgy billets, the beryllium smelter product, vacuum cast ingot, is first converted to chips by machining. The chips are ground to powder finer than 200 mesh, and the powder is then pressed at about 1100°C and in a vacuum of about 50 microns absolute pressure into what is known in the trade as vacuum hot pressed beryllium block. Large or intricate shapes are manufactured from the block by standard machining procedures. Such block usually serves as the starting material for extruded rod and bar and hot-rolled beryllium plate and sheet.

At temperatures over about 1400°F, pure beryllium oxidizes fairly rapidly, and, therefore, all hot working operations, such as extrusion and hot rolling, require that the starting billet be protected from the air during hot working operations. The standard method for accomplishing this is to encase the metal in a mild steel container. At the conclusion of hot working, the steel container is removed, most conveniently by dissolving it in 50 pct nitric acid.

Table II. Elevated Temperature Tensile Test Properties of Beryllium

Test Temp. °F	Strain Rate In./In./Min	U.T.S. (x 1000 Psi)	Yield Strength (x 1000 Psi)	Reduction in Area Pct	Elong. in ¼ In. Pct	Elong. in 2 In. Pct	Mod. (x 10⁶ Psi)
1000	.005	22.4	19.4	7.2	12.7	4.1	37.1
1200	.005	12.5	12.5	2.3	5.5	1.6	31.6
1350	.005	7.7	7.7	1.5	9.1	1.9	17.9
1500	.005	3.1	3.1	2.5	13.2	3.2	5.8
1650	.005	1.3	1.3	7.9	20.4	9.5	3.5

Table III. Comparison of Tensile Properties

Temp. °F	Conventional Metal	Density (Lb/In.³)	Future Tensile Stress Assumed, Psi	Tensile Stress Required of Future Beryllium, Psi
70	Aluminum	0.10	100,000	70,000
400	Titanium	0.17	180,000	70,000
800	Titanium	0.17	130,000	52,000
			150,000	60,000
1200	Steel	0.30	100,000	23,000
			120,000	27,500

Warm extrusion and warm rolling are carried out at temperatures below the oxidation temperature, and, therefore, no protective canning is required. Although warm extruded beryllium exhibits superior strength properties, the high extrusion pressure required has thus far limited the shapes produced to relatively small pieces of small cross-section. Bare warm rolling, while also giving improved physical properties and an excellent as-rolled finish, has not been practiced extensively because of the difficulty of keeping the metal hot enough during rolling.

Beryllium, both hot and warm rolled, has demonstrated sufficient isotropic ductility between 900° and 1100°F to permit hot forming. In this temperature range the metal can be sheared and holes can be punched without difficulty. Successful sheet metal fabrication requires that the tools as well as the metal be maintained at the operating temperature throughout the forming operations, and, except for hole punching, the rate of bending or drawing must be relatively slow. The scale of demand for fabricated parts has been small until recently, therefore, commercial practice closely resembles laboratory procedure.

The brittleness exhibited by beryllium at room temperature is much less in evidence at elevated temperatures. In spite of this, it is found that fabrication of beryllium at high temperatures is relatively difficult to carry out. Cracking of the metal during rolling or forging and, to a lesser extent, during extrusion, is apt to occur, and special precautions must be taken to avoid it.

Fabrication of aircraft components

Beryllium can be hot-formed (1000° to 1400°F) into typical airframe shapes. It may be necessary to use heated tools to maintain the metal temperature. Cold forming (and cold straightening) should not be attempted.

The machining of beryllium can be accomplished to any desired degree of precision. The metal is dimensionally very stable. The only important limitations are the need for protecting the operator from the toxicity hazard and the desire to collect uncontaminated chips for re-use.

Joining: The projected use of beryllium as a structural material makes it imperative that means be devised for joining beryllium to itself and to other metal components of an assembly. Conventional joining techniques have been investigated extensively, with promising results. Brazing has been found to be most satisfactory where it can be used.

Several properties of the metal lead to difficulty in welding and brazing: 1) ease of oxidation at elevated temperatures; 2) the low ductility of the metal; and 3) the high specific heat and the high heat of fusion, requiring a high power input for fusion welding.

A preliminary investigation has shown that, given suitable pretreatment, the adhesive bonding of beryllium is feasible. In this study, failures occurred in the metal at stresses ranging from 37,000 to 52,000 psi.

Facilities

The reduction of beryllium metal billet cost from the levels in excess of $100 per lb experienced during the late 1940's to a low of $47 per lb has been a direct result of increased demand which has given stimulus to the beryllium metal industry.

The recent contracts for beryllium metal billets placed with two privately-owned companies represent a significant change from the previous government-owned, one-source beryllium metal facility. This change has stimulated constructive technical and production research and great interest among aircraft manufacturers.

Suggestion for research

The following are offered as topics to be considered in a research effort which has the objective of using beryllium in aircraft and missile airframes. The order of listing is not intended to reflect any implied priorities.

1. One of the more intriguing research prospects concerns a possible phase change in pure beryllium. Such a transformation (to an undetermined structure) has been reported, at a temperature only about 15° below the melting point. If this finding is confirmed, there would be strong interest in learning whether beta beryllium is ductile, and whether the phase could be retained to room temperature by alloying.

2. The solid solubility limits for oxygen, hydrogen, and nitrogen have apparently never been determined. The importance of this is in connection with purification attempts. Impairment of ductility, if any, is probably due to the gases in solid solution; gas content above this level is of secondary importance. The solubility level of gases in beryllium is apparently quite low; therefore, any program on purification should be accompanied by a refinement, or at least an assessment, of analytical techniques.

3. The question of whether oxygen-free metal will be ductile should be resolved. It might be very expensive to obtain a few grams of pure metal, but, if this beryllium is truly ductile, attempts to deoxidize commercially can be started. The possibility that other gases are important to mechanical behavior should not be ignored.

4. Since the ductility of beryllium is not great, the degree to which this is impaired by notches and surface imperfections should be studied. Such an investigation should include not only slow tensile elongation, but also complex stressing and rapid (impact) loading.

5. Accurate determinations of the solubility levels of zinc, cadmium, and lithium in beryllium would be of value, since these elements are of potential interest for alloying.

6. While improved ductility is strongly desired, there are applications for beryllium with its present ductility but with higher strength. Work has been reported in which copper additions have raised the strength without impairing ductility. This could well be followed up, using other alloying elements.

7. As is true with all metals, desirable mechanical properties of beryllium are associated with a fine grain size. Commercial beryllium is now a −200 mesh sintered powder product, this particle size being a compromise, because below this size the oxide content associated with the particle surface becomes excessive. If a finer grain size can be obtained, without at the same time adding objectionable amounts of oxygen, it would be expected that improved mechanical properties would result.

8. Such progress as has been obtained in improving the ductility of beryllium is a result of working the metal so as to cause a crystallographic alignment. Further improvement would be aided by a more detailed knowledge of matters, such as the critical resolved shear stress for slip and the manner in which fracture propagates. The ductility at elevated temperatures is quite satisfactory, but the variation of the mechanisms of slip and fracture as temperature is raised is not well understood. Several sets of slip planes must be active to permit grain rotation (without voids) in the production of textures. With better knowledge of the plastic properties of beryllium, it might be possible to predict and produce the optimum textures.

9. The presence of a ductile-brittle transition temperature for beryllium has not been established or disproved. Although usually associated with body-centered cubic metals (beryllium is hexagonal), the considerable increase in ductility with increased temperatures raises the possibility that there is a transition temperature for beryllium.

10. The possibility that beryllium could be processed in a fashion to maintain random crystal orientations and also contain a small amount of well-dispersed porosity, or of a dispersed, weak, and isotropic second phase should be looked into. It has been found that dense Al_2O_3 is brittle, but a similar specimen containing several per cent porosity has appreciable ductility at the same high temperatures.

Application research

1. Develop analytical techniques for impurities, especially for gases.

2. Develop beryllium-base alloys aiming for substantial ductility.

3. Determine practical maximum size and minimum gage sheets, and practical limitations of joints.

4. Develop extrusion and sheet-forming techniques to get improved ductility and to reduce cost. Other fabricating processes should also be investigated with the same objective. Previous development has varied working and annealing schedules, with the preferred orientations obtained and the ductility values measured in a tensile test as the criterion. Similar experimentation should be carried out, using as the guiding mechanical test the bend ductility of a wide sheet. Thus, a new *optimum* processing may be found that provides sufficiently high ductility in the least ductile direction to permit relief of high local complex stresses without fracture.

5. Develop methods for making and keeping beryllium very fine grained after casting, extruding, rolling, etc.

6. Improve methods so as to reduce scrap loss and permit the economical re-utilization of scrap.

7. Among the additional property data required are strength and impact values at very low temperatures. A continuation of the collection of high temperature data is in order. Data corresponding to notched specimens covering all the usual properties are needed. Finally, all these data should be obtained on several of the more important grades of metal, such as flat-rolled sheet, cross-rolled sheet, and extrusions.

8. Work should be supported on the development of composite materials containing a substantial fraction of beryllium. It might be possible to utilize some of the peculiar properties of beryllium, perhaps sacrificing some other desirable attributes to obtain a structural element adequate to withstand the loading conditions of a particular application.

AIME OFFICERS:
PRESIDENT—AUGUSTUS B. KINZEL
PAST-PRESIDENT—GROVER J. HOLT
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TREASURER—C. R. DODSON
SECRETARY—ERNEST KIRKENDALL
AIME STAFF:
ASS'T. SECRETARIES—J. B. ALFORD, H. H. APPLETON, J. C. FOX, R. W. SHEARMAN
ASS'T. TREASURER—JOHN LYNCH
FIELD SECRETARY & ASS'T. SECY.—R. E. O'BRIEN, 707 NEWHOUSE BLDG., SALT LAKE CITY 1, UTAH

AIME NEWS

THE METALLURGICAL SOCIETY TO PRESENT BALANCED PROGRAM AT ANNUAL MEETING

The Metallurgical Society of AIME has arranged for the 1959 Annual Meeting a balanced program on the various phases of its activities in the science and engineering of metals. The Iron and Steel Division has planned sessions on ore reduction in blast furnaces and special processes, and the manufacture of steel both by conventional processes and by the newer basic oxygen operations. Vacuum melting for special alloys will also be a subject of one of the sessions. The Physical Chemistry of Steelmaking Committee has arranged for presentation of a paper on *Reduction of Iron Ore* as well as papers on the kinetics, thermodynamics, and the operation of fluidized beds. A session on *Iron Blast Furnace Engineering* will develop important general aspects of heat generation and distribution in relation to furnace operations. Of special significance at the Iron and Steel sessions will be a paper based on the operating data of the basic oxygen steelmaking process at the Aliquippa works of Jones & Laughlin Steel Corp. to be presented by D. R. Loughrey. This will be followed by a paper by H. B. Emerick on *Roll of High-Purity Oxygen in Metallurgical Processes.*

The Extractive Metallurgy Division will conduct a total of 14 sessions, three of them to be held jointly with the Iron and Steel Division. These particular sessions will cover the kinetics of liquid metal reactions,

(Continued on page 744)

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The request for establishment and the proposed bylaws of the Hudson-Mohawk Local Section were approved. The Section will comprise the following counties in New York State: Albany, Broome, Chenango, Columbia, Cortland, Delaware, Dutchess, Greene, Montgomery, Otsego, Rensselaer, Saratoga, Schenectady, Schoharie, Sullivan, Tioga, and Ulster.

It will also comprise the members of The Metallurgical Society of AIME in Berkshire County in Massachusetts if such are released by the Boston section.

Electric Furnace Conference Plans

The Electric Furnace Conference, scheduled to be held at the Statler Hotel in Detroit, December 3-5, will feature additional technical sessions this year on the *Manufacture of Ferro Alloys, The Manufacture of Calcium Carbide, and Other Products,* and on *Electrode Holders.* Usual sessions on production of electric furnace steel for ingots and for castings will also be held. Details of the program are given on page 747 of this issue.

The Fellowship Dinner is scheduled for Thursday evening, December 4, with the principal address to be given by M. K. Schnurr, President, Stainless and Strip Division, Jones & Laughlin Steel Corp., Detroit, Mich. His talk is entitled *Commercial Aspects of Stainless Steels in our Economy.* The toastmaster on this occasion will be K. D. Cassidy, Group Director, Body Group, Ford Motor Co., Dearborn, Mich.

Plant trips will be run on Wednesday, December 3, to the Stainless Steel Div. of Jones & Laughlin Steel Corp., and the Rouge Plant of Ford Motor Co.

Rocky Mountain Minerals Conference Scores a Hit

Beaming at the Rocky Mountain Minerals Conference this past September 17-19th, are (clockwise) A. B. Kinzel, President of AIME, S. D. Michaelson, President of the Society of Mining Engineers, and W. R. Hibbard, Jr., President of The Metallurgical Society and H. C. Pyle, AIME President-Elect.

Under the sponsorship of the Utah AIME Section, the Rocky Mountain Minerals Conference was held at the Newhouse Hotel in Salt Lake City, September 17-19. Registration numbered over 600. Papers presented were of interest to mining engineers, metallurgists, and petroleum engineers.

Special recognition was given to the importance of this conference with scheduled meetings in Salt Lake City of the AIME Board of Directors, as well as meetings of

(Continued on page 745)

Internal Stresses and Fatigue in Metals Symposium Held by GM

The General Motors Corp.'s Technical Center in Detroit was the headquarters of a two-day symposium (September 4-5), on internal stresses and fatigue in metals. Designed to provide an opportunity for an exchange of information and ideas in the vital field of internal stress and fatigue, the GE symposium stressed fundamental research for the first time, coordinated with applications of research.

Guests and speakers attending represented leading universities, independent research institutes, government laboratories, industries, and technical societies in the U.S., U.K., France, Belgium, and Germany.

Twenty technical presentations were made at the symposium headquarters, including six by staff members of General Motors Corp.'s Research Laboratories. General chairman was G. M. Rassweiler, G.E. Research Laboratories.

Eighty-two metal physicists, metallurgists, and engineers attended the four sessions. Topics covered were: **Session I**—*Concepts and Significance of Internal Stresses;* **Session II**—*Crystal Lattices, Imperfections, and Stresses;* **Session III**—*Dislocations, Internal Stresses, and Fatigue;* and **Session IV**—*Fatigue and Related Phenomena.*

Balanced Meeting Program

(Continued from page 743)

application of phase equilibria to metallurgy, and electric furnace methods. The Extractive Metallurgy Division, as customary, will have sessions on the process metallurgy of copper, lead, zinc, and the light metals.

The Extractive Metallurgy Division will conduct several half-day sessions on plutonium metallurgy, which will be sponsored jointly with the Institute of Metals Division.

The Institute of Metals Division is conducting sessions organized by the Physical Metallurgy Committee, the High Temperature Alloys Committee, and by the Chemistry and Physics of Metal Committee. The Chemistry and Physics of Metals Committee has organized two sessions, one based on observations of dislocations, and the second on interfaces and surfaces. The principal speaker at the symposium on observations of dislocations will be Dr. Peter Hirsch of Cambridge University, who will speak on *Direct Observations of Dislocation Motions in Metals.* The Institute of Metals Division is planning to hold a number of sessions based on the submission of research abstracts.

The Annual Fellowship Dinner of The Metallurgical Society will be held on Tuesday evening, February 17, at the St. Francis Hotel in San Francisco.

Nuclear Society Hosts Convention in Detroit

American Nuclear Society will present 150 papers on nuclear science and technology at its annual meeting scheduled for December 8, 9, 10 in Detroit.

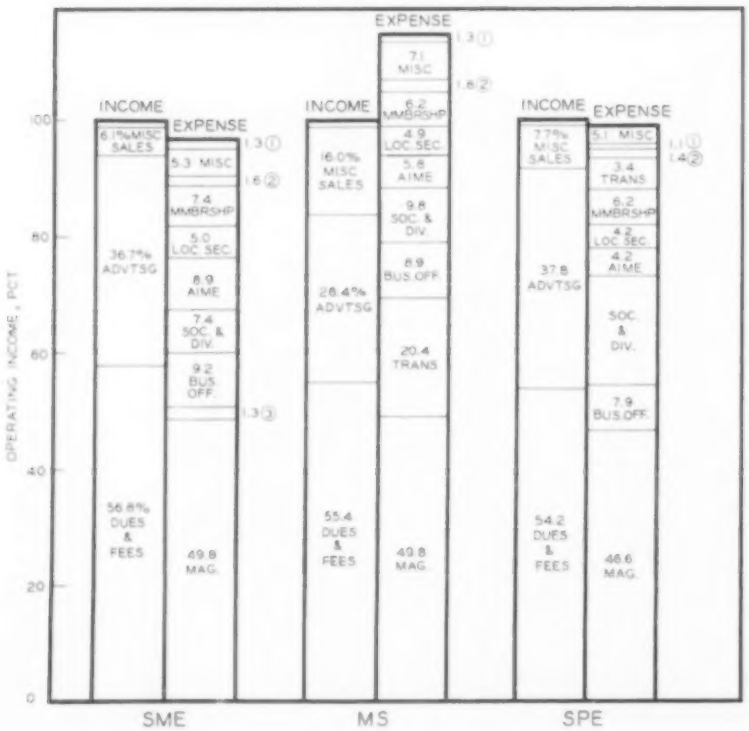
The highlight of the program will be discussions by leading nuclear scientists and engineers on recent atomic energy concepts, such as reactor, engineering, and kinetics.

In addition, there will be field trips to the Enrico Fermi Atomic Energy Plant, Michigan's first generating atomic-electric station, as well as to the Phoenix Project of the University of Michigan, and the Plymouth Automobile plant of the Chrysler Corp.

Special sessions will also review the major events of the U.N. Atoms for Peace Conference, held this past September 1-13.

Alton P. Donnell, general manager of Atomic Power Development Associated, Inc. and Harvey A. Wagner, manager of system development for Detroit Edison, are in charge of local arrangements for the meeting.

THE METALLURGICAL SOCIETY'S OPERATING INCOME AND EXPENSE



How MS Income is Used—

Expressed in terms of Income Dollar Based on 1957 Figures

	INCOME	EXPENSE
SME	$380,000	$369,000
MS *	225,000	260,000
SPE	354,000	351,000

* The Metallurgical Society deficit was made up by appropriations from the Metals Research Publications Fund.

LEGEND

In the chart to the left, circled numbers represent:

1) Library assessment
2) Directory expense
3) Transactions Volume costs

Unmarked space at top of income columns represents miscellaneous income items such as interest.

U. S. Papers on Geneva Atom Conference Now Available from OTS

The United States Atomic Energy Commission has published all the technical papers which were presented by the American nuclear scientists at the Second International United Nations Conference on the Peaceful Uses of Atomic Energy.

This conference, which was held in Geneva from September 1 through 13, featured more than 600 papers from U. S. scientists. The papers included such studies as the biological effects of radiation; chemistry and chemical engineering; the fabrication of fuel elements; geology and mining exploration; high energy physics; isotopes in agricultural sciences; biochemistry, physiology, and medicine.

Also included in this set are papers on the methods of separating isotopes; metallurgy and materials; reactor physics; and thermonuclear developments.

A complete list of these papers can be obtained for 25 cents from the *Office of Technical Service, U. S. Department of Commerce, Washington 25, D. C.*

Conference Papers on Atoms Published by United Nations

The Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy are being published by the United Nations this year. It will be the only complete and official version.

More than 2250 scientific papers were submitted to the 1958 conference as compared to the 1000 in 1955. Such broad topics as Nuclear Power Plant; Use of Isotopes; Basic Physics; and the Economics of Nuclear Power were discussed.

Previous to the publication of this volume, the United Nations compiled 16 volumes from the First International Conference in 1955 which later became one of the major scientific publications for the year.

A 15 pct discount will be given for the purchase of these 34 vols. before November 30. There is, in addition, to the English edition, abridged versions in French and Spanish.

New Titanium Research Catalogs

Three Catalogues of Technical Reports (CTR's) for the field of titanium have just been published by the Office of Technical Services (OTS). The catalogs list all reports of research on the metal, its alloys, carbides, and compounds, and bari-

(Continued on page 748)

ROCKY MT. CONFERENCE Continued from page 743

Among those who participated in the conference were, (left to right) Roger V. Peirce, AIME Director, W. B. Stephenson, President of Allen-Sherman-Hoff Pump Co., R. W. Lawson, Ingersoll-Rand Co., Assistant Convention Manager, Rocky Mountain Minerals Conference, and R. R. McNaughton, Manager, Metals Division, The Consolidated Mining and Smelting Co. of Canada Ltd.

the Board of Directors of The Metallurgical Society and of the Society of Mining Engineers.

Of particular interest to extractive metallurgists was the paper, *Effect and Control of Impurities in the Electrowinning of Zinc* by Guy T. Wever, zinc plant superintendent, The Anaconda Co., Great Falls, Mont. Mr. Wever pointed out that a great number of variable factors encountered in the electrolytic method of producing zinc results in varying methods for each plant, as since no two plants treat exactly the same materials. The speaker hoped that his paper would be the start for more information being made available about the action of impurities in the zinc electrolyzing process.

In his paper, *Research in the Minerals Industry*, B. D. Thomas, president of Battelle Memorial Institute, Columbus, Ohio, stressed that the objectives of industrial research are to improve the operations of industry through reduced cost, improved processes, improved products, new products, and new uses for old products. Dr. Thomas pointed out that the expenditures for the minerals industry for research is not large when calculated as a percentage of sales. He concluded with an appeal for more research in spite of the current depressed state of the mineral industry.

Trends in Mineral Engineering Education, a paper by John W. Vanderwilt, president, Colorado School of Mines, Golden, Colo., was of general interest to all. Dr. Vanderwilt reviewed engineering curriculum today. He stressed the need for study of the humanities, and the possibility of greater time for courses through a six-day school week and a shorter vacation. He concluded with an appeal for leadership by AIME in continuing studies and discussions on mineral engineering education, considering it, a challenge that should be of personal interest and concern to every member of AIME.

Opening the technical session on Wednesday morning, September 17, was a movie on *The Copper Network*, and on Thursday, September 18, a movie on *Columbia-Geneva Coal Preparation Plant*. Papers were also given on such subjects as processing nickel and cobalt ores, recent developments in pebble milling, progress in commercial atomic power, progress in oil shale research, and automation in the minerals industry. Additional papers covered mining and petroleum engineering subjects.

The technical sessions were concluded on Friday morning with a symposium on *Modern Management Techniques*. Participating were W. B. York, division industrial engineer, Utah Copper Division, Kennecott Copper Corporation; Carlos Efferson, manager, organization planning, Kaiser Aluminum & Chemical Corp., Oakland, Calif., and Jack J. Hayes, superintendent of management instruction, United Air Lines, Cheyenne, Wy.

At the Welcoming Luncheon on Wednesday, September 17, opening remarks were given by Lamont F. Toronto, Secretary of State of Utah. Guest speaker was Miles P. Romney, manager of the Utah Mining Association. The day was concluded with a cocktail party, courtesy of mining companies and suppliers.

The Minerals Luncheon was held on Thursday noon, with Howard C. Pyle, President-Elect of AIME, the featured speaker.

On Friday afternoon, registrants had their choice of three tours. One group visited the Kennecott Research Laboratory, the Bureau of Mines Experimental Station, and the University of Utah Atomic Reactor. A second group inspected the equip-

(Continued on page 746)

AROUND THE SECTIONS

REPORT ON RUSSIAN STEELMAKING PROGRESS

The Southern Ohio Section of the National Open Hearth Steel Committee featured a report on *Impressions of the Russian Steel Industry* by Michael F. Yarotsky, at their twenty-second Annual Conference, held at the Dechler-Hilton Hotel in Columbus, October 3 and 4. Attending the conference were 175 registered guests.

Mr. Yarotsky, superintendent of steel production at the South works of United States Steel Corp., Chicago, Ill., was the lead-off speaker. Mr. Yarotsky was one of nineteen steel experts who visited the Soviet Union in May and June of this year under the auspices of the American Iron and Steel Institute. Steel plants were visited at Chelyabinsk, Magnitogorsk, Stalinsk, Sverdlovsk, Zaporstahl, and Tula. The latter plant, not far from Moscow, serves as an experimental and development center—a pilot plant for the steel industry. Here new ideas are tried out in blast furnaces, open hearths, and pneumatic methods of steel production, as well as continuous casting of steel. In explaining how the Soviet Union has accomplished the feat of expanding to an estimated 59,000,000 tons of production in 1958, Mr. Yarotsky stressed that this has been carried out without regard for cost or the need for consumer goods. He credited these factors: 1) thorough and prompt dissemination of all available technical information from all over the world; 2) allotment of 12 per cent of the budget of the Soviet Union to education; 3) recognition of need for excellence in raw materials for the furnaces, with a concentration on beneficiation of ores; and 4) elimination of the bottlenecks that cause production delays.

The operating sessions on Friday morning and afternoon followed the schedule outlined on p. 624 of the September issue of JOURNAL OF METALS.

The first day of the Conference concluded with a Fellowship Dinner at which Vernon W. Jones, Chairman of the National Open Hearth Steel Committee served as toastmaster. Speaker of the evening was Dr. Tennyson Guyer, a well known lecturer and executive assistant and director of public relations at Cooper Tire and Rubber Co., Findlay, Ohio. In an inspirational message, Dr. Guyer stressed the importance of working and living with *people*, and learning from associations with them.

On Saturday morning, the Executive Board of the National Open Hearth Steel Committee held its semi-annual meeting, presided over by Vernon W. Jones, Chairman. The Conference closed with a popular social event, the Ohio State vs. University of Washington football game.

Contributing to the success of the meeting were Paul G. Sammet, Chairman of the Southern Ohio Section, and superintendent of open hearths, Armco Steel Corp., Ashland; R. K. Thornberry, Vice-Chairman; and O. W. Morris, Secretary-Treasurer, and Orville W. Morris, combustion engineer, Armco Steel Corp., Ashland.

► Rendezvous for the September 10th meeting of the **El Paso Section,** was the Hotel Cortez, El Paso, Texas. Fifty-six persons attended the meeting, which was presided over by chairman, John E. Douglas. The guest speaker was Dr. Joseph R. Smiley, president, Texas Western College, El Paso, Texas. He spoke to the section on *Recent Trends in Engineering Education.* Plans for the section's November 12th meeting include Edward Beck of the East Pittsburgh office of Westinghouse Electric Corp. as the featured speaker. Mr. Beck will present a travelogue of his experiences in Russia last year during an engineering meeting with various Russian engineers.

► September 12th marked a meeting of the **St. Louis Section,** held at the Hotel York in St. Louis, Mo. The speaker of the evening was Glenn M. Hanson, process development engineer, processing machinery department, Allis-Chalmers Mfg. Co., who talked on the history and development of the Grate-Kiln system for pyro-processing of iron ores and other materials. Business transacted at the meeting included the distributing of pledge cards to members to be used for the solicitation of funds for the new United Engineering Center. The nominating committee reported the following new officers for 1959: Chairman, Gill Montgomery; vice-chairman, Gordon M. Bell; and secretary-treasurer, Norman S. Geist.

► A joint dinner-meeting of the **Montana Section** with the Anaconda Aluminum Co's technical society was held on September 27th. This special occasion, known as the *Annual Columbia Falls Meeting,* was featured at the Anaconda Aluminum Co.'s Employees Club, Columbia Falls, Mont. The after-dinner speaker, Mr. Lee Holscher, engineer at Kaiser's Trentwood plant, Spokane, discussed *The Fabrication of Aluminum.* A dinner at the Big Mountain Chalet, Whitefish, Mont., was held for the visiting ladies. The transportation for this social event was provided by the Anaconda Aluminum Co's technical society. The following day, members and their wives inspected the Anaconda Co's aluminum plant.

Russian Steelmaking, Topic at Chicago Section Meeting

The Chicago Section held a dinner meeting on October 1 at the Chicago Bar Association, attended by 175. Featured speaker was Dennis J. Carney, Division Superintendent, Steel Production, United States Steel Corp., Duquesne Works, Duquesne, Pa. His topic was *Steelmaking in Soviet Russia.* In his provocative talk, Dr. Carney stressed these points: 1) the Russians locate their steel plants near sources of ore rather than proximity to markets; 2) the Russians have increased the productive capacity of iron and steelmaking units through increased heat size and auxiliary equipment, *e.g.* charging machines and cranes, augmented furnace crews, greater supervision, and utilization of latest advances in technology; 3) their top management is efficient and well trained; 4) production is increased through workable incentive systems; and 5) education for steel metallurgists is thorough and specific. Michael F. Yarotsky, Division Superintendent, Steel Production, United States Steel Corp. South Works, Chicago, served as Technical Chairman of the meeting.

Rocky Mt. Conference

(Continued from page 745)

ment manufacturing plant of Eimco Corp. and the chemical fertilizer plant of Western Phosphates, Inc. A non-technical tour to Big Cottonwood Canyon and its ski-lift to Mt. Millicent was the third choice offered.

Throughout these three days, since the ladies were not forgotten, they were invited to the luncheons and the cocktail party. A special Ladies Luncheon and Fashion Show was also held for their benefit at the Salt Lake Country Club on Thursday afternoon. Concluding the three-day affair was a gala Dinner Dance on Friday evening.

Responsible for the success of the Conference were the Utah Section officers, R. C. Cole, Chairman; Glen A. Burt, Vice-Chairman; N. L. Weiss,

(Continued on page 748)

Condensed Program

1958 ELECTRIC FURNACE CONFERENCE

Sponsored by the Electric Furnace Committee of the Iron and Steel Division, The Metallurgical Society of The American Institute of Mining, Metallurgical, and Petroleum Engineers

Statler Hotel, Detroit, Michigan—December 3, 4, and 5, 1958

WEDNESDAY, DECEMBER 3, 1958

9 am to 9 pm **Registration**

1:00 pm **Plant Trip**

Chartered buses will leave from the Bagley Street entrance of the Statler Hotel at 1:00 pm. There is a choice of visiting either the Stainless Steel Division of Jones & Laughlin Steel Corp., or Rouge Plant of Ford Motor Co. (The capacity for the plant trip to Jones & Laughlin Steel Corp. is 100.) Buses will return to the Statler Hotel by 5:00 pm. Cost of tickets, $2.00.

THURSDAY, DECEMBER 4, 1958

8:30 am **Registration**

9:30 am **Opening Session**

Welcoming remarks; salute to automobile industry; introduction of group on production of carbides, alloys, metals, and phosphorus in electric furnaces.

9:45 am **Joint General Session—Manufacture of Ferro-Alloys**

Electric furnace ferro-alloy industry in the United States; manufacture of ferro-silicon alloys; casting of ferro-alloys; control of quality in ferro-alloy manufacture.

2:00 pm **Joint General Session—Physical Chemistry of Steelmaking**

Review of technical conference on *Quality Requirements of Super Duty Steels*, Pittsburgh May 5-6, 1958; effect of vacuum stream degassing on properties of forging steels.

6:30 pm **Reception and Cocktail Party**

7:00 pm **Annual Fellowship Dinner**

Speaker: M. K. Schnurr, President, Stainless and Strip Div., Jones & Laughlin Steel Corp., Detroit, Mich.; Toastmaster: K. D. Cassidy, Group Director, Body Group, Ford Motor Co., Dearborn, Mich., Title: *Commercial Aspects of Stainless Steels in Our Economy.*

FRIDAY, DECEMBER 5, 1958

8:30 am **Registration**

9:30 am **Ingot Session on Stainless Steel—Production and Applications**

Present and future application of stainless steel products in the automotive industry; developments in melting operations.

9:30 am **Casting Session of Foundry Practices**

Effect of various additions to the electric arc and induction furnace on gas contents; pinhole porosity in high-alloy steel castings made in green-sand molds; high frequency induction melting of steel in furnace unit up to 5½ ton capacity; oxidation and deoxidation practice in the high-frequency induction furnace.

9:30 am **Special Arc Group Session on Manufacture of Calcium Carbide and Other Products**

A brief history of calcium carbide manufacture; tapping and casting of calcium carbide; electric furnace production of special irons and titania slag; electrically smelted oxides and metalloids of zirconium and titanium.

2:00 pm **Ingot Session on Melting; Cost Reductions**

Use of direct reduced iron in the electric furnace; simplified calculation of effects of oxygen blowing rates; linear programming of the material costs of stainless steel.

2:00 pm **Castings Session on Special Operating Technology**

Effect of phosphorus and sulfur content on the ductility and toughness of cast low alloy steels; desulphurization of steel by the injection of lime and aluminum-magnesium alloy; improving electric furnace refractory life by special shell cooling techniques; split heat techniques.

2:00 pm **Special Arc Group Session on Electrode Holders and Planning Session**

Electrodes holders; planning and organization for future meetings.

Titanium Catalog

(Continued from page 745)

um titanate available to the public from the OTS collection.

They include CTR 349, Titanium—Part I: Titanium and Alloys, 1930-1958; CTR 350, Titanium—Part II: Titanium Carbides and Compounds, 1920-1958; and CTR 351, Titanium—Part III: Barium Titanate, 1946-1958.

CTR's may be ordered from the *Office of Technical Services, US Department of Commerce, Washington 25, D. C.*, for 10 cents each.

Membership—Many Opportunities; Only Member Effort Required

With Metallurgical Society and AIME activities gaining momentum, opportunities for gaining new members are increasing at a rapid rate. In addition to a full schedule of local section meetings, December will see an enlarged Electric Furnace Conference, with technical sessions covering uses of electric furnaces throughout industry. Such expanded technical coverage provides a golden opportunity for expanding our membership into new industrial areas.

Local section meetings as well as technical conferences provide numerous opportunities to tell the nonmembers in attendance about the advantages of AIME membership. Opportunities must be grasped, however. Welcome non-members to meetings, and offer to help them in completing an application. The recently revised Metallurgical Society application form contains up-to-the-minute information about meetings, publications, and advantages of membership. If forms are not available at local section meetings, ask your section secretary or membership chairman, who should have a supply on hand.

You needn't go to meetings to spread the word about AIME, however. The headquarters staff will be happy to do the job for you. All that is required is for you to notify AIME of the names of persons who you believe are qualified but are not presently members of The Metallurgical Society. The handy form below, when completed and returned to *Room 912, 29 W. 39 Street, New York 18, New York*, will result in your prospective member receiving a cordial invitation to membership, along with an application form and information about the Society.

The Metallurgical Society can only be effective when it includes as many metals men as possible—its growth insures your growth, technically and professionally, as well as that of the metallurgical profession.

Rocky Mt. Conference

(Continued from page 746)

Vice-Chairman; and P. H. Ensign, Secretary-Treasurer; and the Conference Committee, A. J. Thuli, General Chairman; and Assistant General Chairman, R. W. Lawson. Credit also goes to Mrs. Ralph Tuck, Chairman of the Women's Auxiliary, and her capable associates.

Armour Foundation Dedicates a New Research Addition

The Metals Research Building Addition of the Armour Research Foundation of the Illinois Institute of Technology was dedicated this past October. Dr. J. H. Hollomon, manager of the metallurgy and ceramics research department, of the General Electric Research Laboratory was the luncheon speaker. At the conclusion of an excellent address and luncheon, the guests were taken on a tour of this modern, beautiful laboratory.

Change of Address and Personals Form

To be sure that you receive your publications and correspondence promptly, please fill in the form below and send it to **The Metallurgical Society of AIME**, 29 W. 39th St., New York 18, N.Y.:

Name _____

Old Address _____

_____

_____

New Address _____

_____

_____

Personals: Please list below your former company and title and your new title and company (or new work) for use in JOURNAL OF METALS. (Copy deadline for personals items is six weeks before date of issue.)

Former Company _____

Former Title _____ Length of Time There _____

New Company _____

New Title _____ Date of Change _____

Any recent activity that would be of interest to members:

_____

_____

_____

_____

PROPOSAL FOR AIME MEMBERSHIP

I consider the following person to be qualified for membership and request that a membership kit be mailed to him:

Name of Prospective Member:

_____

Address

_____

_____

_____

Name of AIME Member:

_____

Address

_____

_____

_____

JM

PERSONALS

John Stuart Smart has been appointed general sales manager of American Smelting & Refining Co. Mr. Smart will now work directly with Mr. Simon Strauss, vice president in charge of sales, and will be responsible for the administration of the sales departments, and for the sales of the company's metal products and by-products.

Prior to his promotion, Mr. Smart was assistant director of research.

OBITUARIES

Stewart J. Cort, (Member 1948) Vice-president of Bethlehem Steel Co., and the first recipient of the *Benjamin F. Fairless Award of AIME* in 1955, died September 23rd, after a long illness. Born in Ogle County, Illinois, in 1881, Dr. Cort attended Lehigh University and was awarded a degree in electro metallurgy in 1906, and a doctor of engineering degree in 1948. His professional career began in 1906 in the open hearth department of the Duquesne works of the Carnegie Steel Co. Three years later, he was made assistant superintendent of the steel division of the same company. In 1916, he became superintendent of the steel division of the Cambria plant of Midvale Steel and Ordnance Co. and in 1917 was made superintendent of the Saucon division open hearths at the Bethlehem plant of Bethlehem Steel Co., becoming in 1922, superintendent of the entire Saucon division. In 1928, Dr. Cort became general manager of the Sparrows Point plant of Bethlehem Steel Co., and in 1948 was elected vice-president in charge of the steel division. He was a director of that company until the time of his death. The citation accompanying the Fairless Award to Dr. Cort read *"For his leadership in iron and steel manufacturing which he has made his company an outstanding producer in the industry.*

Chung Yu Wang (Member 1905) research director for the Wah Chang Corp., died on August 30, 1958. Dr. Wang was an authority on non-ferrous metals and built the first antimony refinery in China, for the Wang Chang Mining and Smelting Co. Dr. Wang also served as a councilor to the Chinese delegation to the Washington conference, in 1922 and was a delegate to a world mining congress in Japan. He was also technical expert for the Chinese Ministry of Industry in Nanking and Chungking, and served as president of the Association of Chinese and American Engineers in China. At the time of his death, Dr. Wang resided at 501 West 123rd St., New York City.

Carl K. Stewart (Member 1948) metallurgist and chemist for International Nickel Company died on June 27, 1958. Mr. Stewart had a long and varied career in the metallurgy and chemical fields. He started his career in 1917, as an iron and steel analyst at Carnegie Steel, and held such positions as research metallurgist, consulting chemist, and development metallurgist during his long career in the field. At the time of his death, Mr. Stewart resided in New Jersey.

Frederick A. McCoy (Associate Member 1954) works metallurgist for Sheffield Division, Armco Steel Corp. died on August 25, 1958. At the time of his death Mr. McCoy lived in Kansas City.

Ernest Klepetko (Member 1915) consultant for the Electrolytic Zinc Plant, Design and Research, died on June 27, 1958. While with Combined Metals Co., Mr. Klepetko developed a process for the recovery of resin from Utah coal. Mr. Klepetko had also been associated with Anaconda Co., and Cyprus Mines Corp. At the time of his death, Mr. Klepetko resided in Denver.

Ernest A. Brown (Member 1953) died on May 15, 1958. Dr. Brown was chief of the radioactivity division, Dept. of Mines and Technical Surveys, Ottawa, Canada. During his career, he worked on the recovery of elemental sulfur and production of iron oxide by roasting of pyrite in a controlled atmosphere, and on the production of metallic magnesium by ferrosilicon reduction of calcine dolomite. At the time of his death, he resided in Ottawa, Canada.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Sept. 1, 1958 was 30,496; in addition 3,125 Student members were enrolled.

ADMISSIONS COMMITTEE

J. H. Scaff, Chairman; Alfred Bornemann; F. B. Foley; T. D. Jones; L. L. Seigle; J. M. Warde; H. K. Work.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Henry E. Bridgers, Allentown, Pa.
John F. Chapman, Pittsburgh, Pa.
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Coy L. Huffine, Cincinnati, Ohio
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NECROLOGY

Date Elected	Name	Date of Death
1953	E. A. Brown	May 15, 1958
1929	E. Klepetko	Jun. 27, 1958
1954	F. A. McCoy	Aug. 9, 1958
1948	C. K. Stewart	Jun. 27, 1958
1905	C. Y. Yang	Aug. 30, 1958

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COMING EVENTS

Nov. 2-6, AIME Chicago Section, Institute of Metals Division, Fall Meeting, Hotel Sherman, Chicago.

Nov. 7, AIME Pittsburgh Section, Thirteenth Annual Off-the-Record meeting, Pittsburgh.

Nov. 11, AIME NOHC Buffalo Local Section, fall meeting, Statler Hotel, Buffalo.

Nov. 20, AIME Utah Section, speaker: James C. Strong, *Engineering Aspects of the Great Salt Lake Crossing Project.* Mr. Strong is with the construction division of Southern Pacific Co.

Nov. 17-20, The Fourth Conference on Magnetism and Magnetic Materials, sponsored by the AIEE, in cooperation with The Metallurgical Soc. of AIME, The American Physical Soc., the Inst. of Radio Engineers, and the Office of Naval Research, Sheraton Hotel, Philadelphia.

Dec. 3-5, AIME 16th Electric Furnace Conference, Statler Hotel, Detroit.

Dec. 11, AIME Utah Section, Panel discussion on the Place of Research in the Minerals Industries, Salt Lake City.

Jan. 15, AIME Utah Section, speaker: Harold Wright, *Rubber and Plastic as Cost Savers in Metallurgical Installations.* Mr. Wright is executive vice-president of Galigher Co.

Feb. 15-19, 1959, AIME Annual Meeting, St. Francis Hotel, Sheraton-Palace Hotel, and Sir Francis Drake Hotel, San Francisco.

Apr. 2-3, 1959, AIME Technical Conference on Stress Corrosion, Mellon Institute, Pittsburgh.

Apr. 6-8, 1959, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 5-10, 1959, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 27-30, 1959, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPA.

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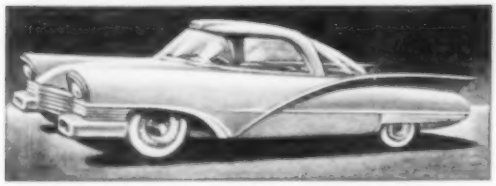

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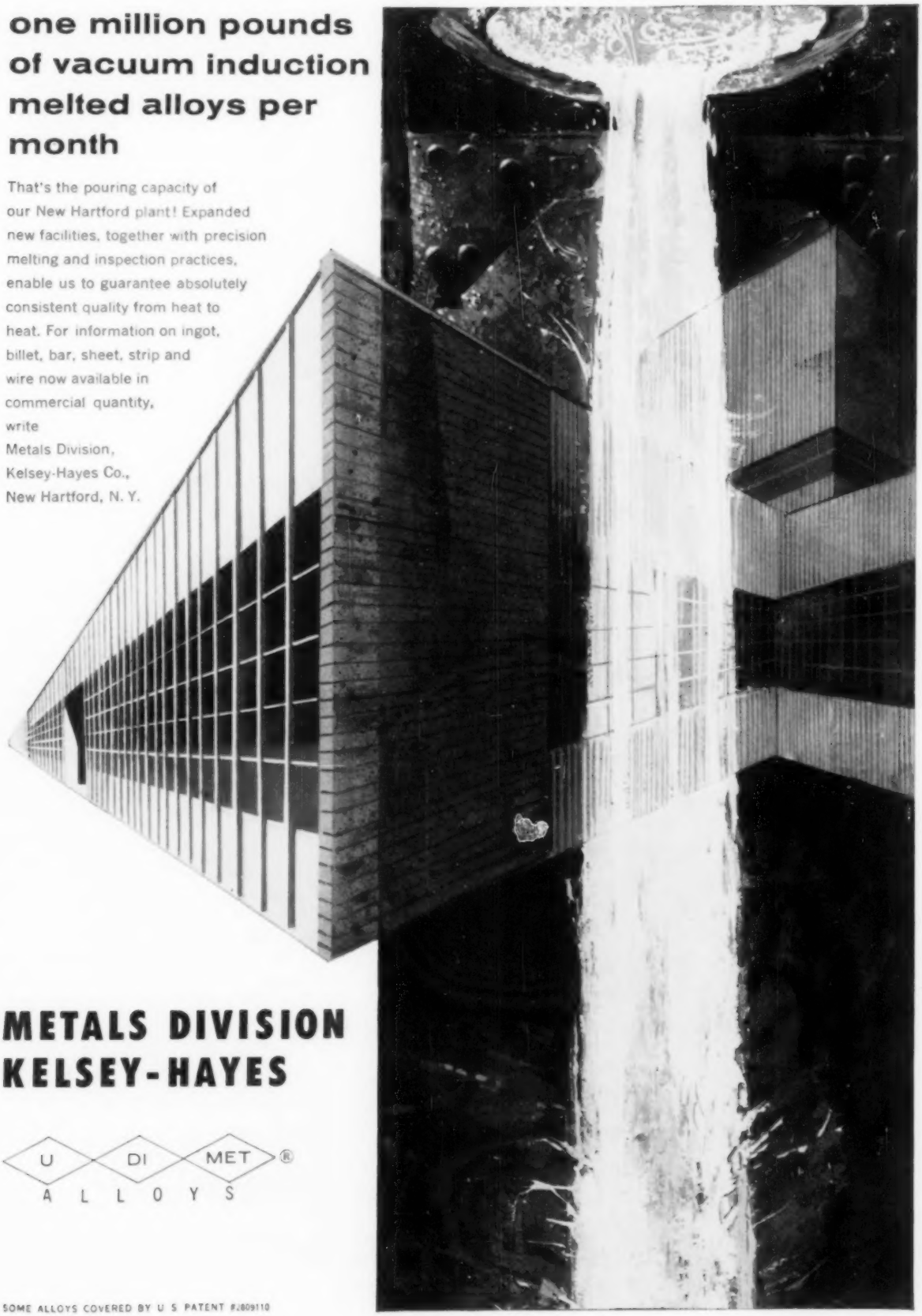

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